US Army Corps of Engineers

COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

INSTRUCTION REPORT ITL-90-1

USER'S GUIDE: COMPUTER PROGRAM FOR DESIGN AND ANALYSIS OF SHEET PILE WALLS BY CLASSICAL METHODS (CWALSHT)

by

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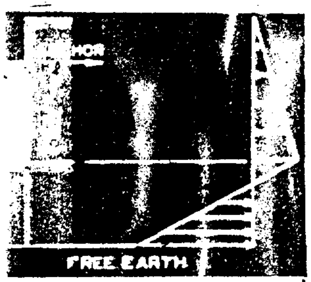

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Final Report

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PROGRAM INFORMATION

Description of Program

CWALSHT, called X0031 in the Conversationally Oriented Real-Time Program-Generating System (CORPS) library, performs design and/or analysis of either a cantilever or an anchored sheet pile wall. The program uses classical soil mechanical procedures for determining the required depth of penetration of a new wall or assesses the factor of safety for an existing wall. Seepage effects are included in a simplified manner in the program.

Coding and Data Format

CWALSHT is written in FORTRAN and is operational on the following systems:

a. WES Honeywell DPS/8.

b. Local District Harris 500 Series.

c. Power Computing Company, Cyber 865.

d. Micro Computer IBM PC/XT/AT compatibles.

e. Intergraph workstations.

Data can be input interactively at execute time or from a prepared data file with line numbers. Output may be directed to an output file or come directly back to the terminal.

How to Use CWALSHT

A short description of how to access the program on each of the three systems is provided. It is assumed that the user knows how to sign on the appropriate system before trying to use CWALSHT. In the example initiation of execution commands that follow, all user responses are underlined, and each should be followed by a carriage return.

WES Honeywell System

The user signs on the system and issues the run command.

FRN WESLIB/CORPS/X0031,R

to initiate execution of the program. The program is then as described in this user's guide. The data file should be prepared prior to issuing the FRN command. An example initiation of execution is as follows, assuming a data file had previously been prepared:

COEWES HIS TIMESHARING ON 12/15/86 AT 11.175 CHANNEL Ø145 TS2
USER ID --RØKACLA
PASSWORD--
*USERS=Ø2Ø SS=Ø251K %MEM-USED=Ø68 ØØØ-WAIT-ØØØK
1Ø.187**ALL USERS SEE INFO SIGNON FOR WONDERFULLY GOOD NEWS!!!*******
*FRN WESLIB/CORPS/XØØ31,R

Power Computing Company
Computer System

The log-on procedure is followed by a call to the CORPS procedure file

OLD,CORPS/UN=CECELB

to access the CORPS library. The file name of the program is used in the command

BEGIN,,CORPS,XØØ31

to initiate execution of the program. An example is:

CONNECTED TO 1Ø-17
86/12/15 11.1Ø.35 AC2DSHA
SN1Ø48 POWER COMPUTING COMPANY NOS1.4-531-795-A
FAMILY: KOE,CERØC2
USER NAME: CERØF8
PASSWORD
XXXXXXX
TERMINAL: 6, NAMIAF
RECOVER/ CHARGE: CHARGE,CERØGC,CERØF8
$CHARGE,CERØEGC,CERØF8.
/
1Ø.36.21. WARNING

12/15/86, SEE EXPLAIN, WARNING.
OLD,CORPS/UN=CECELB
/BEGIN,,CORPS,XØØ31

Harris System

The user signs on the system and issues the run command

*CORPS,XØØ31

to initiate execution of the program.

An example is:

"ACOE-WES(H5ØØ V5.1.1)"
ENTER SIGN-ON
11KABC ROKABC

** GOOD MORNING CORPS-LIB, IT'S 15 DEC 86 11:42:3Ø
WES HARRIS 5ØØ FOR SYSTEM INFORMATION - ENTER *NEWS
*CORPS,XØØ31

How to Use CORPS

The CORPS system contains many other useful programs which may be catalogued from CORPS by use of the LIST command. The execute command for CORPS on the WES system is:

```
FRN WESLIB/CORPS/CORPS,R
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST
```

On the Power Computing Company computer system, the commands are:

```
OLD,CORPS,/UN=CECELB
BEGIN,,CORPS,CORPS
ENTER COMMAND (HELP,LIST,BRIEF,MESSAGE,EXECUTE, OR STOP)
*?LIST
```

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The computer program CWALSHT was developed from specifications provided by the Computer-Aided Structural Engineering (CASE) Task Group on Sheet Pile Structures and is described in this report. The program uses classical soil mechanics procedures for determining the required depth of penetration of a new wall or assesses the factors of safety for an existing wall.

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Computer-Aided Structural Engineering Project	Retaining walls
Computer programs	Safety factor
CWALSHT (computer program)	Sheet piles

CATEGORY B

ELECTRONIC COMPUTER PROGRAM ABSTRACT

TITLE OF PROGRAM	PROGRAM NO.
Design/Analysis of Sheet Pile Walls by Classical Methods - CWALSHT (XØØ31)	713-F3-RØØ92

PREPARING AGENCY US Army Engineer Waterways Experiment Station (WES), Information Technology Laboratory, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199

AUTHOR(S)	DATE PROGRAM COMPLETED	STATUS OF PROGRAM: PHASE	STATUS OF PROGRAM: STAGE
Author: Dr. William P. Dawkins Adapted for CORPS	Written - Jan 1990 Adapted - Jan 1990	COMPLETE	

A. PURPOSE OF PROGRAM

Performs either a design or analysis of an anchored or cantilever sheet pile retaining wall.

B. PROGRAM SPECIFICATIONS

FORTRAN

C. METHODS

Uses classical soil mechanics procedures for determining the required depth of penetration of a new wall or assesses the factor of safety of an existing wall.

D. EQUIPMENT DETAILS

Graphics Terminal or PC AT or compatible

E. INPUT-OUTPUT

Input may be entered from a predefined data file or interactively at execute time.

Output will be directed to an output file and/or directly back to the terminal.

F. ADDITIONAL REMARKS

A copy of the program and documentation may be obtained from the Engineering Computer Programs Library (ECPL), WES, telephone number: commercial (601)634-2581.

PREFACE

This user's guide describes the computer program, "CWALSHT," that can be used for the design and analysis of cantilever and anchored sheet pile walls using classical methods. CWALSHT supercedes the computer program called "CSHTWAL" and is documented in US Army Engineer Waterways Experiment Station (WES) report IR-K-81-2. Funds for the development of the program and writing of the user's guide was provided to the Information Technology Laboratory (ITL), WES, Vicksburg, MS, by the Civil Works Directorate of Headquarters, US Army Corps of Engineers (HQUSACE), under the Computer-Aided Structural Engineering (CASE) Project.

Specifications for the program were provided by the members of the CASE Task Group on Pile Structures and Substructures. The following were members of the task group during program development:

Mr. James Bigham, Rock Island District (Chairman)
Mr. Richard Chun, Pacific Ocean Division
Mr. Ed Demsky, St. Louis District
Mr. John Jaeger, WES (formerly St. Louis District)
Mr. Phil Napolitano, New Orleans District
Mr. Charles Ruckstuhl, New Orleans District
Mr. Ralph Strom, North Pacific Division

The computer program and user's guide were written by Dr. William P. Dawkins, P.E., Stillwater, OK, under contract with WES.

The work was managed and coordinated at WES, ITL, by Mr. Reed Mosher, Computer-Aided Division (CAED), and Mr. H. Wayne Jones, Chief, Scientific and Engineering Application Center, CAED, under general supervision of Dr. Edward Middleton, Chief, CAED, Mr. Paul Senter, Assistant Chief, ITL. and Dr. N. Radhakrishnan, Chief, ITL. Mr. Donald Dressler was the HQUSACE point of contact for this work.

COL Larry B. Fulton, EN, is the present Commander and Director of WES. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC)
UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degree (angle)	0.01745329	radians
feet	0.3048	metres
inches	2.54	centimetres
pound (force)-feet	1.355818	newton-metres
pound (force)-inches	0.1129848	newton-metres
pounds (force)	4.448222	newtons
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (mass) per cubic inch	27,679.905	kilograms per cubic metre
pounds (force) per foot*	14.5939	newtons per metre
pounds (force) per inch	175.1268	newtons per metre
pounds (force) per square foot	47.88026	pascals
pounds (force) per square inch	6.894757	kilopascals
square inches	6.4516	square centimetres

* The same conversion factor applies for pounds (force) per linear foot (PLF).

USER'S GUIDE: COMPUTER PROGRAM FOR DESIGN AND ANALYSIS OF SHEET PILE WALLS BY CLASSICAL METHODS (CWALSHT)

PART I: INTRODUCTION

Description of Program

1. This report describes a computer program called CWALSHT which performs design and/or analysis of either cantilever or anchored sheet pile walls. The program uses classical soil mechanics procedures for determining the required depth of penetration of a new wall or assesses the factors of safety for an existing wall. Seepage effects are included in a simplified manner in the program. CWALSHT was developed from specifications provided by the Computer-Aided Structural Engineering (CASE) Task Group on Sheet Pile Structures. The program follows as a minimum the procedures outlined in draft Engineer Manual 1110-2-2906 (Department of the Army 1970).

Organization of Report

2. The remainder of this report is organized as follows:

- a. Part II describes the general sheet pile retaining structure and the soil system to be designed or analyzed by the program.
- b. Part III describes the procedures employed in the program for calculating earth pressures on the wall due to adjacent soil, unbalanced hydrostatic head, and surcharge loads on the soil surface.
- c. Part IV reviews the methods for determining the required depth of penetration for each type of wall.
- d. Part V describes the computer program.
- e. Part VI presents example solutions obtained with the program.

3. The program has been checked within reasonable limits to assure that the results obtained by it are accurate within the limitations of the procedures employed. However, there may exist unusual situations not anticipated and thus may cause the program to produce questionable results. It is the responsibility of the user to judge the validity of the final design of the system, and no responsibility is assumed for the design of any structure based on the results of this program.

PART II: GENERAL WALL/SOIL SYSTEM

4. The same basic wall/soil system shown in Figure 1 is used for either anchored or cantilever sheet pile walls. Throughout development of the program it was assumed that all effects on the wall tend to cause counter-clockwise rotation of a cantilever wall and clockwise rotation of an anchored wall. This section presents other assumed characteristics for the various components of the general system.

Sheet Pile Wall

5. A 1-ft* slice of a straight, uniform wall is used for the design/analysis process. The wall is assumed to be straight, initially vertical, linearly elastic, and to have a constant cross section throughout its depth.

Anchor

6. For anchored walls, a single horizontal anchor may be attached to the wall at any elevation at or below the top of the wall. The anchor is assumed to prevent horizontal displacement at the point of attachment.

Soil

7. In subsequent paragraphs, reference is made to the "right" side and "left" side of the wall. The soil surface on either side must intersect the wall at or below the top of the wall.

Soil Surface

8. The irregular soil surfaces illustrated in Figure 1 provide for all variations of soil surface geometry including horizontal or continuous sloping (either up or down away from the wall).

9. A different layered soil profile is assumed to exist on either side of the wall. Boundaries between subsurface layers are assumed to be straight

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

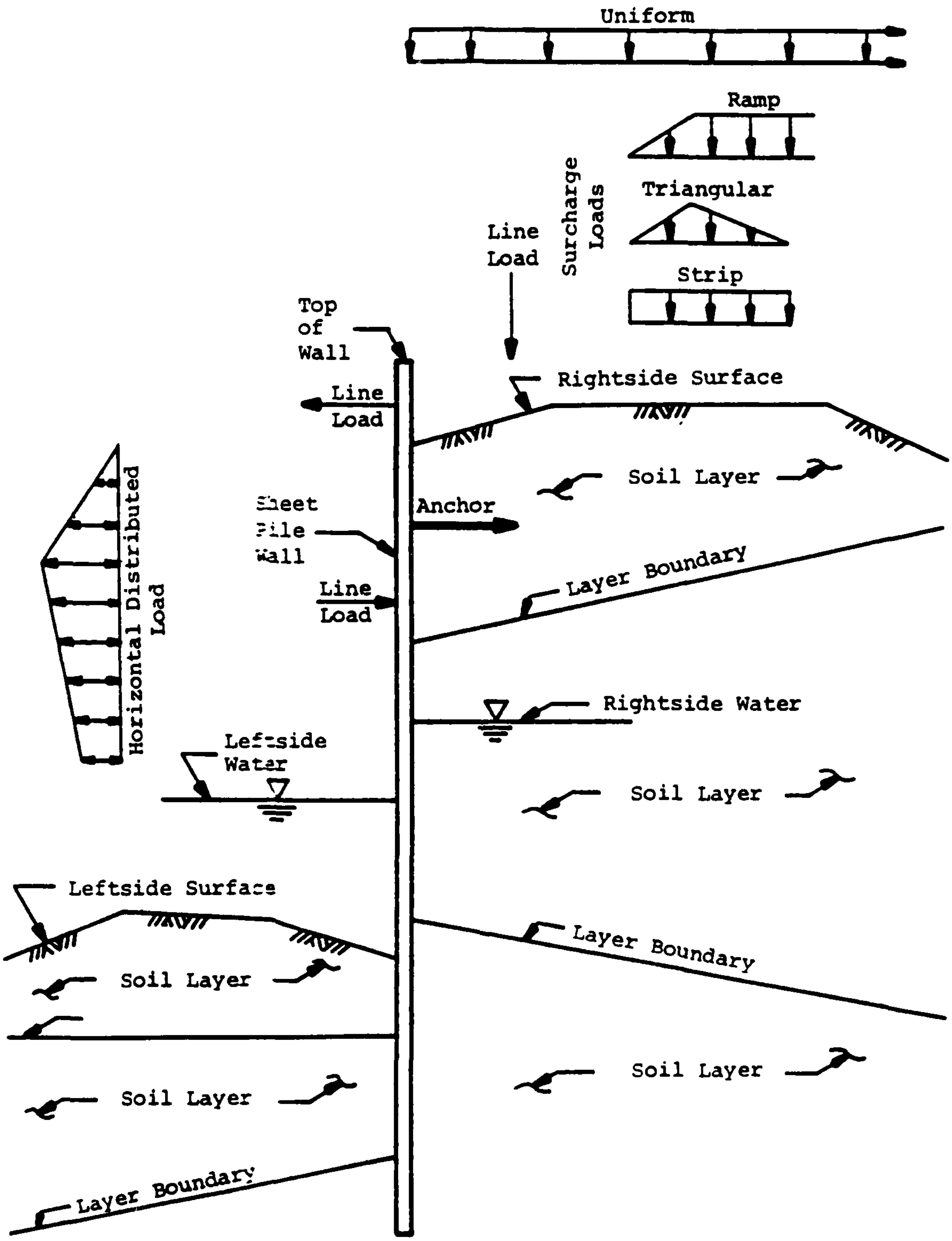


Figure 1. General wall/soil system

lines and may slope up or down away from the wall on either side. Sloping boundaries must not intersect below the soil surface. Layers are assumed to extend ad infinitum away from the wall, and the lowest layer described on either side is assumed to extend ad infinitum downward.

Soil Properties

10. Each soil layer is assumed to be homogeneous. Properties required for each layer are:

a. Soil saturated unit weight--γ_{sat}: The program determines the buoyant unit weight for submerged soil according to

$$\gamma' = \gamma_{sat} - \gamma_{we}$$

where

γ' = buoyant unit weight

γ_{we} = effective unit weight of water (see paragraph 40, Part III).

b. Soil moist unit weight--γ_{mst}: The moist unit weight is used for all soil above the water surface.

c. Actual angle of internal friction--ϕ: The program determines the effective angle of internal friction according to

$$\phi_{eff} = \tan^{-1} [(\tan \phi)/FS]$$

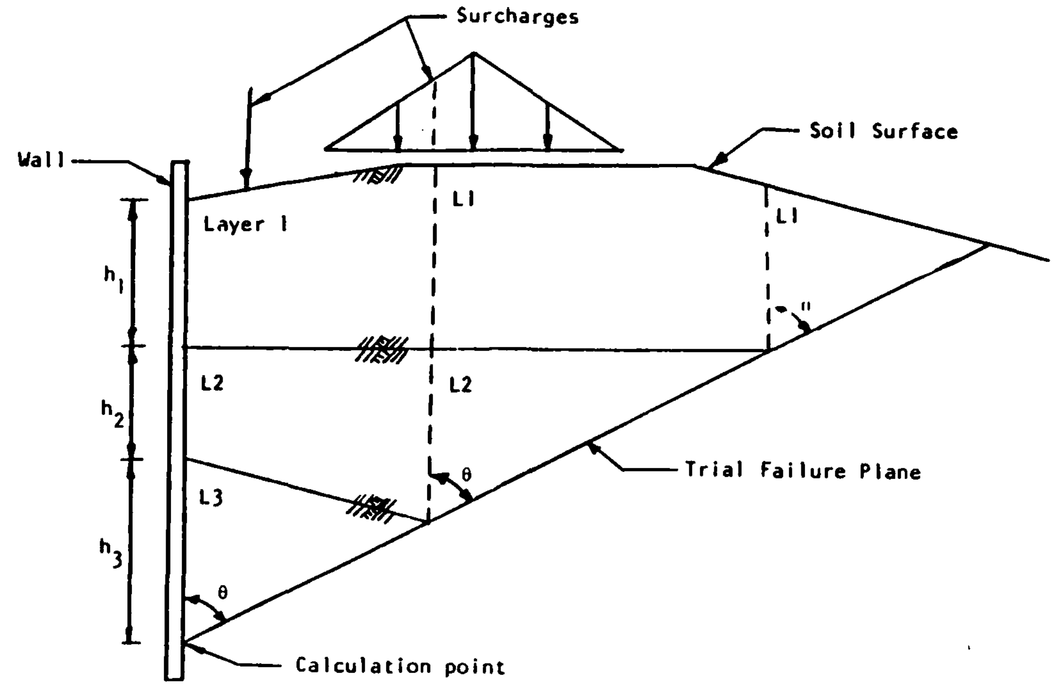
where FS is the given or calculated factor of safety.

d. Actual cohesion--c: The program determines the effective cohesion from

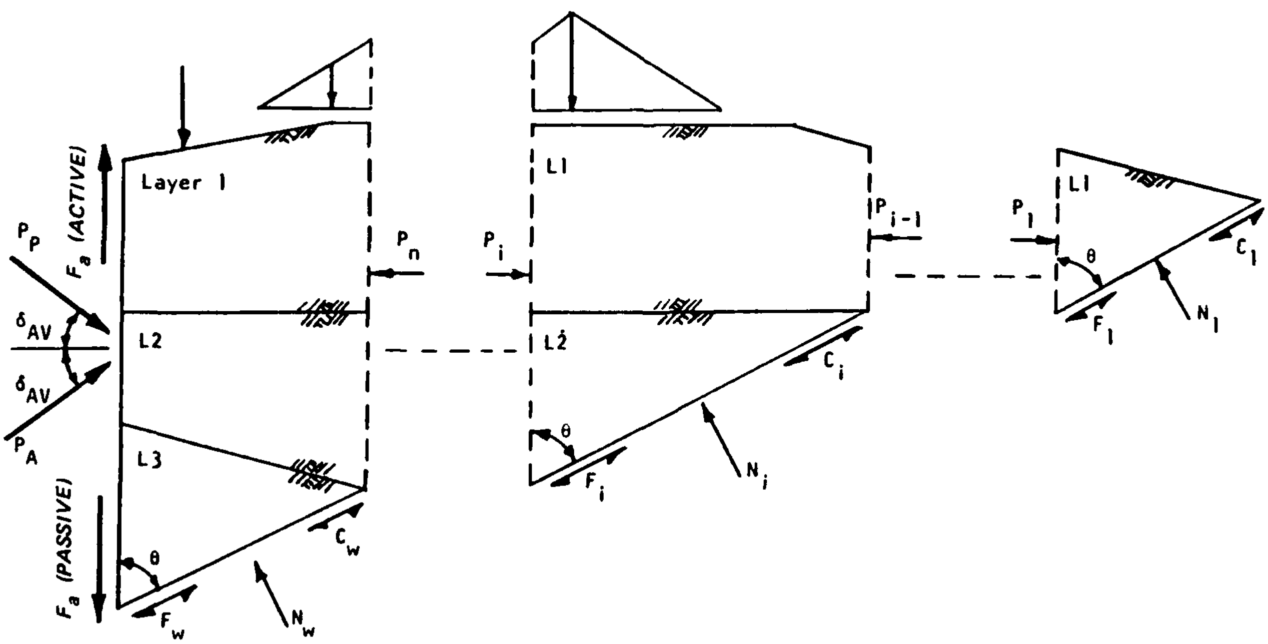
$$c_{eff} = c/FS$$

e. Effective angle of wall friction--δ: The program does not alter the angle of wall friction. See Figure 2 for assumed positive wall friction angle.

f. Effective wall/soil adhesion--a: The program does not alter the adhesion. See Figure 2 for assumed positive direction of the adhesion force.



a. Trial failure wedge



b. Wall slice c. Interior slice d. Terminal slice

Figure 2. Sweep search wedge method

Water

11. The following effects due to water are considered:

   a. Static water. Horizontal pressures due to hydrostatic head are applied on either side of the wall. Static water surfaces may be at any elevation. When the water surface is above the top of the wall, a drop structure is assumed, and only the trapezoidal pressure distribution below the top of the wall is used.

   b. Seepage effects. Seepage effects alter static water pressures and the submerged weight of the soil. The approximations used to account for seepage are discussed in paragraphs 40 and 41. When seepage is present, the water surface on the right side must be above that on the left side.

   c. Earthquake effects. Earthquake effects alter hydrostatic pressures only on the right side above the ground surface (see paragraphs 18 and 19).

Vertical Surcharge Loads

12. Surcharge loads may be applied to the soil surface on either side of the wall. Five types of surcharge loads are illustrated in Figure 1.

Vertical Line Loads

13. Vertical line loads are assumed to extend horizontally parallel to the axis of the wall and to act on the soil surface. The program accommodates 21 line loads at any location on the surface on either side of the wall.

Distributed Loads

14. Four distributed load variations permitted by the program are shown in Figure 1. A general distributed load may also be described by a sequence of distances and load intensities. Only one distributed load on each side is permitted in the design/analysis of a particular wall description. All distributed loads are assumed to extend horizontally parallel to the wall. Distributed loads are interpreted as acting on the horizontal projection of the soil surface. A uniform surcharge is assumed to extend ad infinitum away from the wall. A ramp load is assumed to extend ad infinitum away from the wall beginning at the terminus of the ramp.

External Horizontal Loads

15. Two types of external horizontal loads in addition to other soil and water loads may be applied to the wall. Horizontal loads acting to the left are positive.

Horizontal Line Loads

16. The program permits up to 21 line loads (positive or negative) to be applied directly to the wall at any location at or below the top of the wall.

Horizontal Distributed Loads

17. A single general horizontal load distribution described by elevations and load values for a maximum of 21 points may be applied to the wall.

Earthquake Effects

18. Earthquake effects are assumed to increase the tendency toward rotation of the wall. Earthquake effects on soil pressures are simulated in the program by altering the soil unit weight on each side of the wall as follows:

$$\text{Right side:} \quad \gamma_{eff} = \gamma(1 + \alpha) - \gamma_{we}$$

$$\text{Left side:} \quad \gamma_{eff} = \gamma(1 - \alpha) - \gamma_{we}$$

where α is earthquake acceleration expressed as a fraction of the acceleration of gravity.

19. Earthquake effects on water pressures above the rightside soil surface are included by application of an additional pressure distribution extending from the rightside water surface to the rightside soil according to

$$P_y = C_e \, \alpha\sqrt{hy}$$

where

$C_e = 51/\sqrt{1 - 0.72\ (h/1000)^2}$

h = distance from rightside water surface to rightside soil surface

y = distance below rightside water surface

PART III: LOADS ON WALL

20. Horizontal loads are imposed on the structure by the surrounding soil, surface surcharge loads, water pressures, or horizontal loads applied directly to the wall. The following paragraphs describe the procedures used in the program for determining the resultant horizontal pressure distributions and wall/soil adhesion is zero in all soil layers.

Calculation Points

21. Locations at which force magnitudes and wall response are calculated are initially located at the following points:

- a. At 1-ft intervals starting at the top of the sheet pile.
- b. At the intersections of the surface and/or layer boundaries on either side with the wall axis.
- c. At the point of application of each horizontal line load and at each elevation point of a horizontal load distribution.
- d. At the location of the water surface on either side of the wall.
- e. At the anchor elevation for anchored walls.
- f. At other locations to establish the resultant force or pressure distribution as necessary for each design procedure.

Soil Pressures

22. Three methods (a coefficient method and two "wedge" methods) are available in the program to establish the design pressure distributions. Inherent in each method is the assumption that the wall displaces sufficiently to produce a fully plastic state in the soil on either side of the wall. This assumption results in full values of active and passive earth pressure at every point regardless of actual displacement. The program determines whether the coefficient method or a wedge method is to be used for soil pressure calculations. A different method may be used for each side of the wall.

Pressure Coefficient Method

23. Coulomb earth pressure coefficients relating horizontal pressure to vertical pressure are used when the soil surface is horizontal and all layer boundaries are horizontal.

Pressures by Coefficient Method

24. Soil pressures are calculated as follows:

a. The vertical pressure p_v at each point is calculated using the effective soil-unit weight (including submergence and/or earthquake effects) for the soil above that point and any uniform surcharge.

b. The Coulomb earth pressure coefficients are:

(1) Active pressure coefficient

$$K_A = \left[\frac{\cos \phi_{eff}}{1 + \sqrt{\dfrac{\sin (\phi_{eff} + \delta) \sin (\phi_{eff})}{\cos \delta}}} \right]^2 \cdot \frac{1}{\cos \delta}$$

(2) Passive pressure coefficient

$$K_p = \left[\frac{\cos \phi_{eff}}{1 - \sqrt{\dfrac{\sin (\phi_{eff} + \delta) \sin (\phi_{eff})}{\cos \delta}}} \right]^2 \cdot \frac{1}{\cos \delta}$$

where

ϕ_{eff} = effective angle of internal friction

δ = angle of wall friction (may be positive or negative).

c. Horizontal earth pressures are calculated from:

(1) Active pressures

$$p_{Ah} = \left(K_A \, p_v - 2c_{eff} \sqrt{K_A} \right) \cdot \cos \delta$$

(2) Passive pressures

$$p_{Ph} = \left(K_p \, p_v + 2c_{eff} \sqrt{K_p} \right) \cdot \cos \delta$$

d. When a change in either ϕ_{eff} or c_{eff} occurs at a layer boundary, dual pressure values are calculated using the soil properties above and below the boundary.

Wedge Methods

25. For all cases involving a sloping or irregular soil surface and/or sloping subsurface layer boundaries, one of the wedge methods described is used. The user is prompted by the program to select the method.

Sweep search wedge method

26. A continuous failure plane is assumed to emanate from each calculation point described in paragraph 21 to its intersection with the ground surface as shown in Figure 2a. The total trial wedge is then subdivided by vertical planes into slices as shown in Figures 2b,c,d. The location of the vertical plane is established by the intersection of the continuous trial failure plane with each succeeding layer boundary. The intermediate vertical slice surfaces are assumed to be free of shear stresses. Friction and cohesion forces along the base of each intermediate slice are evaluated from the soil properties of the bottom layer in the slice.

27. Equilibrium of horizontal and vertical forces for each slice except the wall slice results in

$$P_i - P_{i-1} = \frac{W_i(1 \mp \tan \phi_i \tan \theta) \mp C_i \sec \theta}{\tan \phi_i \pm \tan \theta}$$

where

P_i, P_{i-1} = normal forces on left and rightside vertical surfaces of the slice, respectively

W_i = weight of the slice, including

ϕ_i = effective internal friction angle of the soil at the bottom of the slice

C_i = effective cohesion of the soil at the bottom of the slice multiplied by the length of the bottom surface

The upper signs correspond to active conditions, and the lower signs correspond to passive conditions.

28. Equilibrium analysis of the wall slice results in

$$\begin{bmatrix} \pm \sin \delta_{av} & (\sin \theta \pm \tan \phi_w \cos \theta) \\ \cos \delta_{av} & -(\cos \theta \mp \tan \phi_w \sin \theta) \end{bmatrix} \begin{pmatrix} P_{A/P} \\ N_w \end{pmatrix} = \begin{pmatrix} W_w \mp C_w \cos \theta \mp F_a \\ P_n \mp C_w \sin \theta \end{pmatrix}$$

where

$\delta_{av} = \Sigma h_j \delta_j / \Sigma h_j$ = average wall friction angle

$P_{A/P}$ = active force (upper signs) or passive force (lower signs) for this trial wedge

W_w = weight of wall slice including surcharge loads

C_w = effective cohesion of the soil at the bottom of the wall slice multiplied by the length of the bottom surface

$F_a = \Sigma h_j a_j$ = wall/soil adhesion force

N_w = normal force on bottom of wall slice

P_n = normal force on vertical plane

29. The angle of inclination θ of the trial wedge is increased in 2-deg increments until the maximum active force and minimum passive force for that calculation point are determined. In some systems having downward sloping surfaces, maximum active and minimum passive forces may not be achieved before the trial failure plane no longer intersects the soil surface. When this situation is encountered, a warning is printed and the active and/or passive force for the last trial plane is used for that point.

Fixed surface wedge method

30. The fixed surface wedge method assumes that the angle of inclination of the failure plane within each soil layer is a function of the angle of internal friction of the soil in the layer. This assumption results in a single fixed broken failure surface as is illustrated in Figure 3.

31. When the fixed surface for a calculation point has been established, the total wedge is subdivided into slices as indicated by the dashed lines in Figure 3. The determination of active and passive forces on the wall proceeds as described for the sweep search method.

Final Pressures for Wedge Methods

32. For either wedge method it is assumed that the difference between active or passive forces for two adjacent calculation points is the resultant of a linear pressure distribution between the two points.

Discussion of Soil Pressure Calculation Methods

33. The computer program determines from the input data whether the coefficient method may be used or whether a wedge method is required for

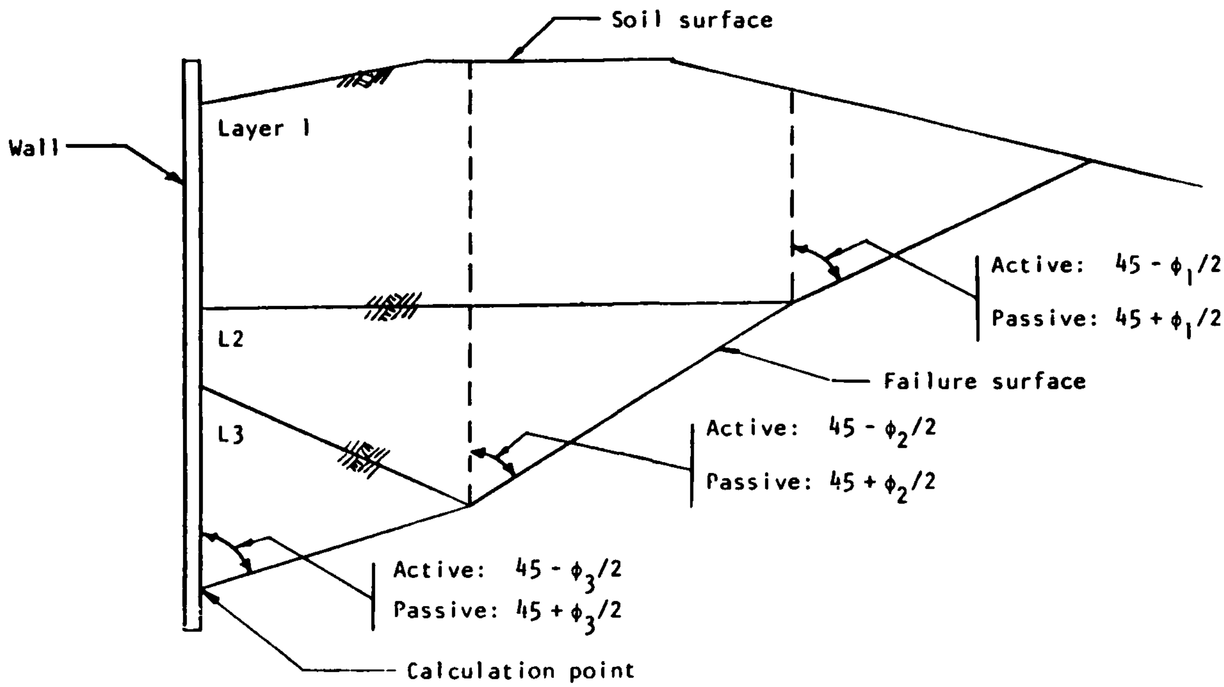


Figure 3. Fixed surface wedge method

evaluation of soil pressures. If a wedge method is required, the user is prompted to select either the sweep search or the fixed surface method. The program can be forced to use a wedge method where the coefficient method would ordinarily apply by specifying more than one point on the soil surface on either side (see Appendix A, Guide for Data Input).

34. For a homogeneous soil system with a horizontal soil surface and no surcharge loads, the three pressure calculation methods produce identical pressure distributions. For layered soil profiles with horizontal layer boundaries, horizontal surfaces and no surcharge loads, the three methods yield essentially the same pressure distributions. The significant differences occur at layer boundaries where the coefficient method may produce discontinuities in pressures while the wedge methods result in a single average pressure at the boundary. Discontinuities arising from the coefficient method are removed from the net pressures by using the average of the two pressure values at the discontinuity.

35. For all soil profiles without severe variations in soil layer strengths and with essentially horizontal surfaces, the two wedge methods produce comparable soil pressures. Although both methods overestimate passive pressures, the sweep search method is more consistent with the principles used in the development of the coefficient method. For systems with steep surface

slopes, the fixed surface wedge method underestimates active pressures for upward sloping surfaces and overestimates passive pressures for downward sloping surfaces as compared to the pressures produced by the sweep search method. The degree of under- or overestimation increases as the surface slope increases.

36. The sweep search method always seeks the maximum active condition and minimum passive condition. It may not be possible for the sweep search method to arrive at the desired extreme condition if the soil surface is grossly irregular. The user is warned when this condition is encountered. In systems with interspersed strong and weak layers, the sweep search method may arrive at an active and/or passive force at one calculation point which is significantly lower than the corresponding force at the next higher point. Conversion of active/passive forces to pressures in this case may result in "negative" pressures in the interval and the resulting pressure distribution is questionable (see Example CANT2, paragraphs 80 and 81).

Net Soil Pressures

37. Four separate soil pressure distributions are determined by the methods just described.

a. Active pressure for the rightside soil.

b. Passive pressure for the rightside soil.

c. Active pressure for the leftside soil.

d. Passive pressure for the leftside soil.

All calculated negative active pressures are set to zero.

Pressures Due to Surcharge Loads

38. The effects of surcharge loads on the rightside surface are included in the weight of the failure wedge, and no additional computations for surcharge loads are required when soil pressures are determined by a wedge method.

39. When the coefficient method is used to determine soil pressures, the additional horizontal pressures on the wall due to strip, ramp, triangular, and varying surcharge loads are calculated from the theory of elasticity equations shown in Figure 4. A uniform surcharge is added directly to the vertical soil pressure as indicated in paragraph 24.

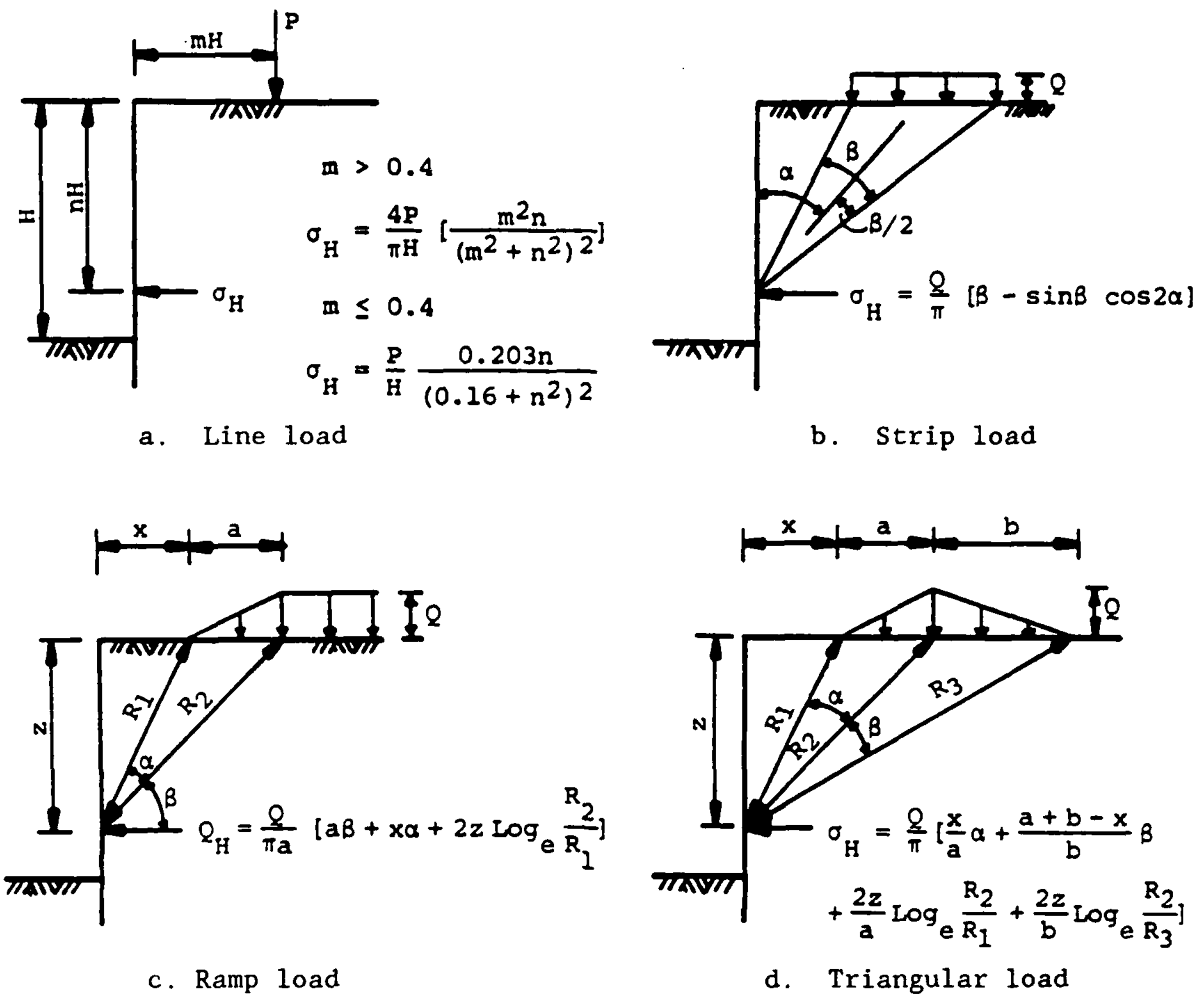


Figure 4. Theory of elasticity equations for pressures on wall due to surcharge loads

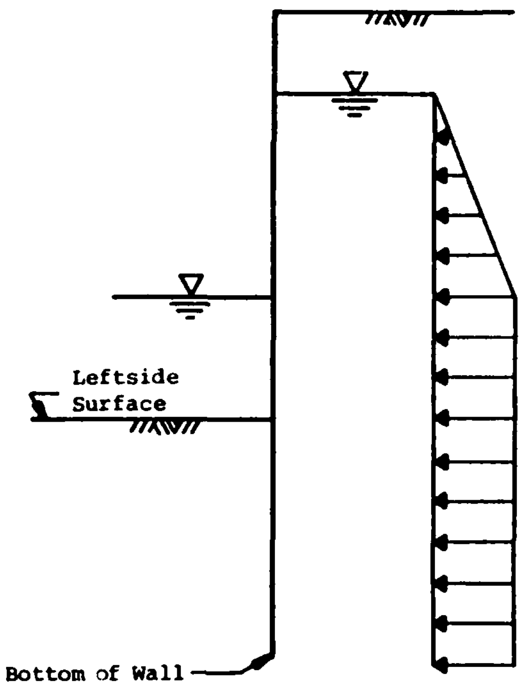
Water Pressures

40. In addition to earthquake effects (paragraphs 18 and 19), hydrostatic pressures may be altered by seepage. When seepage effects are included, the excess hydrostatic head is assumed to be dissipated by vertical flow downward on the right side and upward on the left side. The flow gradient $\underline{i}$ (FT/FT) is assumed to be constant at all points in the soil on either side. Under this assumption, the effect of seepage is to alter the effective unit weight of water in the region of flow to

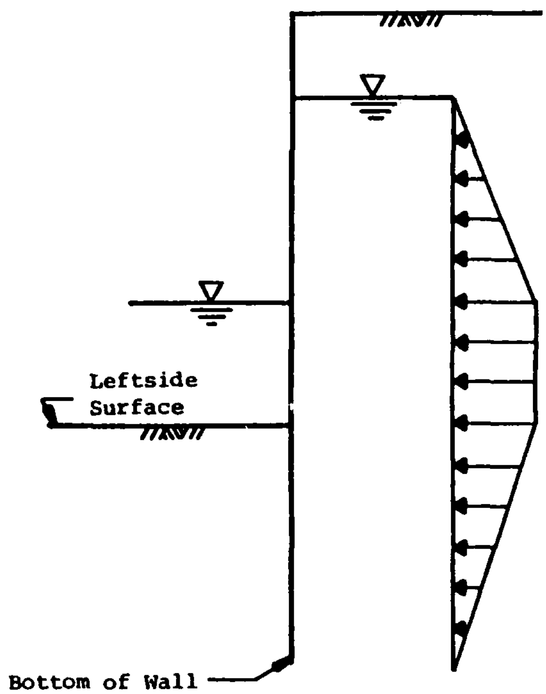
$$\text{Right side:} \quad \gamma_{we} = \gamma_w (1 - i)$$

$$\text{Left side:} \quad \gamma_{we} = \gamma_w (1 + i)$$

41. The user may elect to omit seepage effects, to specify the seepage gradient i , or to allow the program to automatically adjust the seepage gradient. If seepage is omitted, the net water pressure distribution shown in Figure 5a is applied. For "automatic" seepage, the program adjusts the seepage gradient i , so that the point at which excess head is dissipated (i.e., the net water pressure becomes zero, Figure 5b) coincides with the bottom of the wall. Because the determination of design penetration is an iterative process, selecting the automatic seepage option may significantly increase the computer costs for a solution, particularly for systems in which a wedge method is required for soil pressures. When a seepage gradient is specified by the user, the point at which excess head is dissipated may not coincide with the bottom of the wall.



a. Net water pressure without seepage



b. Net water pressure with seepage

Figure 5. Pressure distributions for unbalanced hydrostatic head

Design Pressures

42. The following combinations of all applicable loading effects are used for the final design:

Net Active Pressure = Rightside Soil Active Pressure - Leftside Soil Passive Pressure + Surcharge Pressure + Water Pressure + Distributed External Horizontal Pressure.

Net Passive Pressure = Rightside Soil Passive Pressure - Leftside Soil Active Pressure + Surcharge Pressure + Distributed External Horizontal Pressure + Water Pressure.

Horizontal Loads

43. Horizontal line and distributed loads are applied directly to the wall. Depending on their sense (positive to the left) and point of application, horizontal loads may have either a stabilizing or disturbing effect on the wall.

PART IV: DESIGN/ANALYSIS PROCEDURES

44. The program provides two modes of operation. In the "Design" mode, the required depth of wall penetration is determined for input soil strengths, geometry, loading, and factor(s) of safety. Iterative solutions are performed in which wall penetration is varied until conditions of equilibrium and other assumptions are satisfied. In the "Analysis" mode, a safety factor for input strengths, geometry, loading, and prescribed penetration is determined. In the Analysis mode, a succession of design calculations is performed in which the factor of safety is adjusted until consistent factor of safety and effective soil strength properties yield a design penetration equal to the input value. In unusual layered systems, in which a wedge method is used for soil pressures, it is possible for minuscule changes in the factor of safety to produce a large change in required penetration, indicating a discontinuity in the relationship between factor of safety and penetration. When this condition is encountered, a solution for a unique factor of safety is impossible and the process is terminated.

45. In either the Design or Analysis mode, a structural analysis is performed to determine bending moments and shears in the wall at the locations of the calculation points. Relative deflections (i.e., the deflected shape of the wall) are calculated for both modes of operation. Because the pile moment of inertia is not known a priori in a design situation, the deflections of the wall in the Design mode are determined for wall modulus of elasticity and moment of inertia which are both equal to one. Because the wall is assumed to be a linear system for structural analysis, the "scaled" deflections reported from the Design mode may be converted to actual relative deflections by dividing by the product of modulus of elasticity and wall moment of inertia after these parameters have been selected by the designer.

Factors of Safety

46. In the Design mode, active and passive factors of safety are applied to the soil shear strength in each layer on each side of the wall according to three "levels" of input values. Level 1 active and passive factors of safety apply initially to all soil layers on both sides of the wall. Level 2 active and passive factors of safety apply initially to all soil layers on each side of the wall. Level 3 active and passive factors of

safety are specified for an individual soil layer. Each level of factors of safety may default to the preceding level. Unless defaulted, any specified value of factor of safety overrides the value specified by the preceding level. The user is allowed complete flexibility for applying factors of safety ranging from a single value to be applied to both active and passive pressures for all soil layers to specification of separate active and passive factors of safety for each individual soil layer.

47. Because the sheet pile wall problem has only "one degree of freedom," i.e., the depth of penetration in the Design mode, only one value can be determined for a factor of safety in the Analysis mode. Two options are available for assessment of the factor of safety. If the user specifies the active factor of safety at the three levels described for the Design mode, a single passive factor of safety applied to all soil layers is determined. As an alternative, the user may elect to have the same factor of safety apply to both active and passive effects.

Design Procedures

48. One procedure for cantilever wall design and three procedures for anchored wall design are incorporated in the program. These methods are described in detail by Bowles (1977), Department of the Army (1970), Richart (1960), Terzaghi (1943), and United States Steel Corporation (1974). The essential features of each method are summarized in the following paragraphs.

Cantilever wall design

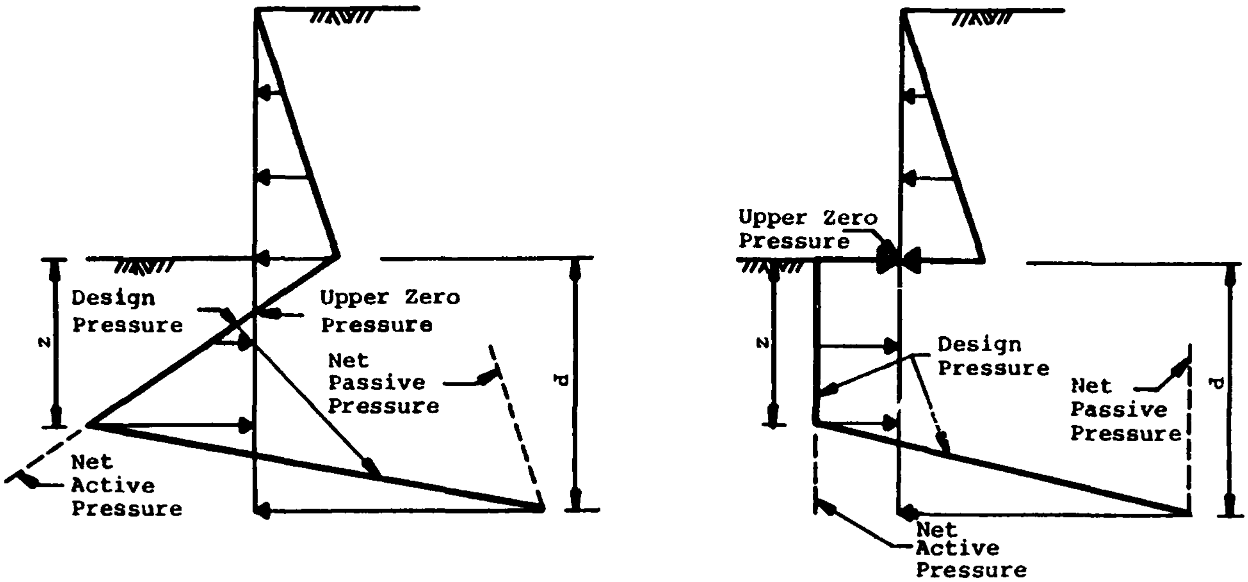
49. The assumptions employed in the conventional design procedure are:

a. The wall rotates counterclockwise as a rigid body about a point somewhere in its embedded depth.

b. Due to the rotation, full active and passive earth pressures are developed on either side.

c. The wall derives its support from passive pressures on each side.

50. Typical simplified pressure distributions arising from the above assumptions are shown in Figure 6. A final design is achieved when values of penetration d and depth z of the transition point produce a pressure distribution for which the sum of moments about any point on the wall and the sum of horizontal forces are simultaneously equal to zero.



a. Homogen.ous granular subsoil   b. Homogeneous cohesive subsoil

Figure 6. Design pressure distributions for cantilever walls

51. The process used in the program to determine the required penetration is as follows. Starting at the first calculation point below the upper zero pressure point (Figure 5), the bottom of the wall (i.e., penetration d) is moved progressively downward until values of d and z are found which produce a horizontal resultant force equal to zero. The resultant moment is then calculated. When a reversal in resultant moment is found, the depth of penetration is adjusted between the last two calculation points until the resultant moment is less than a prescribed minimum tolerance.

52. In the structural analysis cantilever walls, following the design for required penetration or analysis for factor of safety, the bending moments, shears, and relative (or scaled) deflections are calculated under the assumption that the wall is a cantilever beam supported at the wall bottom and subjected to the final net pressures and other external loads.

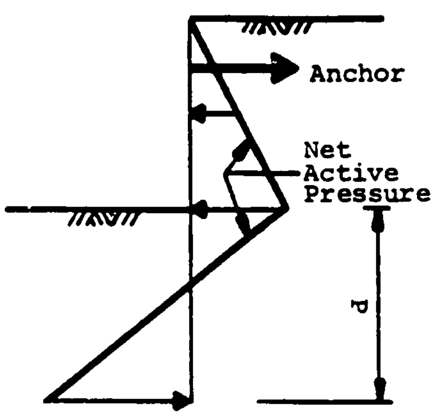
Anchored wall design

53. Three conventional procedures are incorporated in the program for design or analysis of anchored walls. A design or analysis is obtained and reported for each of the methods.

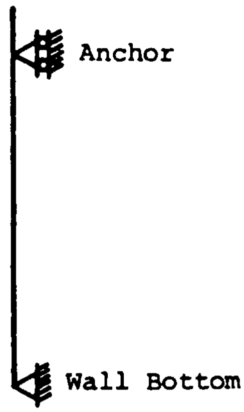
54. In the conventional procedures it is assumed that the motion of the wall will be sufficient to produce full active and passive pressures at every point. In all methods for anchored wall design, the anchor is assumed to prevent any lateral motion of the wall at the point of attachment but not to

inhibit wall rotation (i.e., to be a "pinned" support). It is further assumed that the loading effects tend to cause clockwise rotation of the wall about the anchor.

55. Free earth method. In this method the design penetration d (Figure 7) is established by lowering the bottom of the wall until the sum of moments of all forces about the anchor is equal to zero. The anchor force is then equal to the sum of all horizontal loads.



a. Design pressure

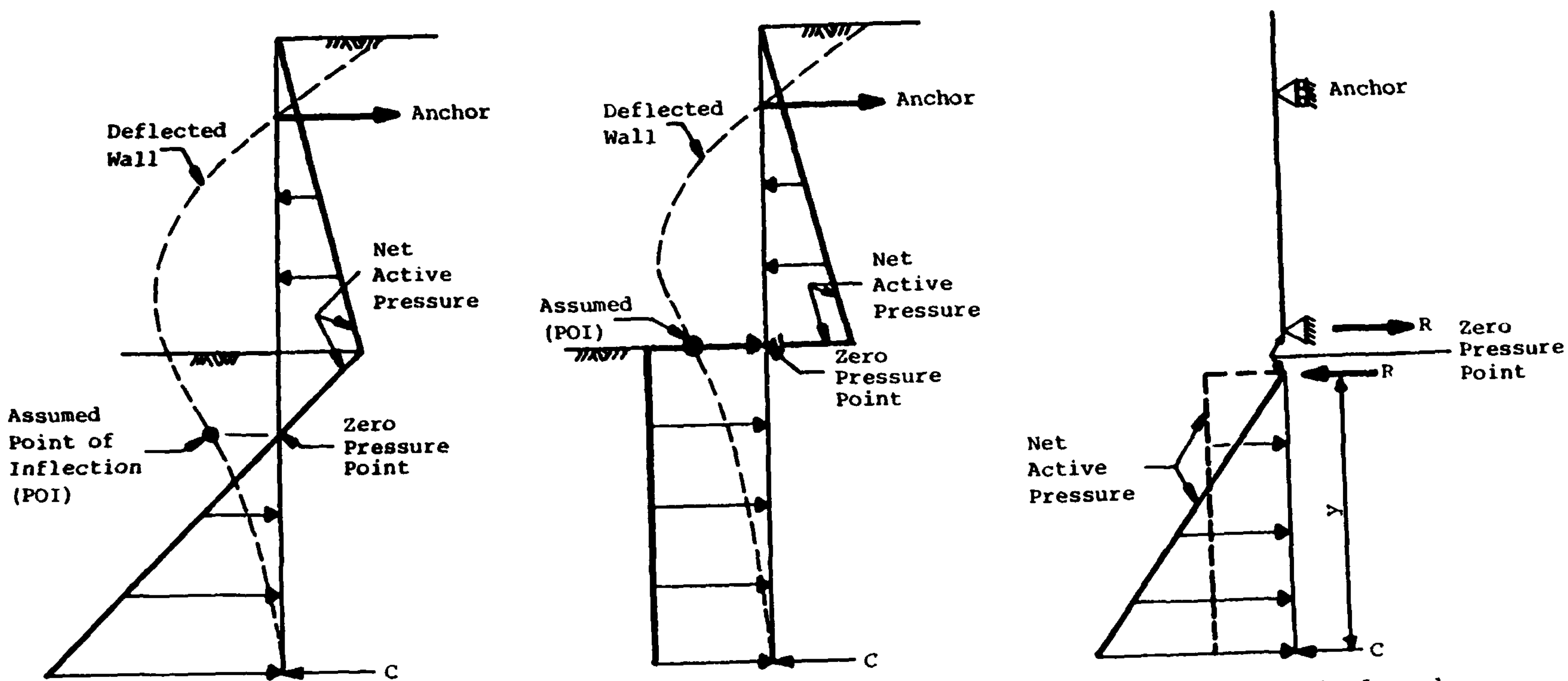


b. Supports for structural analysis

Figure 7. Anchored wall design by free earth method

56. In the structural analysis for the free earth method, bending moments, shears, and deflections are calculated by treating the wall as a beam with simple (unyielding) supports at the anchor and at the wall bottom (Figure 7b). The assumed bottom support has no influence on bending moments and shears and only affects the relative (scaled) deflection values.

57. Equivalent beam method. The fundamental assumption for this method is that the wall is embedded to a depth which produces a point of inflection in the deflected shape at some point below the leftside surface. The program assumes the point of inflection occurs at the first point of zero net active pressure at or below the leftside surface (Figures 8a and b). For design, the portion of the wall above the point of zero pressure (Figure 8c) is treated as a beam on simple supports located at the anchor and at the point of zero pressure. The upper simple beam reaction is equal to the anchor force. The design penetration (i.e., distance y shown in Figure 8c) is determined by lowering the bottom of the wall until the net active soil pressure below the zero pressure point and the lower simple beam reaction R (Figure 8c) produce a zero resultant moment about the wall bottom. (Refer to draft EM 1110-2-2906



a. Granular subsoil

b. Cohesive subsoil

c. Equivalent beam

Figure 8. Anchored wall design by equivalent beam method

(Department of the Army 1970) for additional information on the equivalent beam method.)

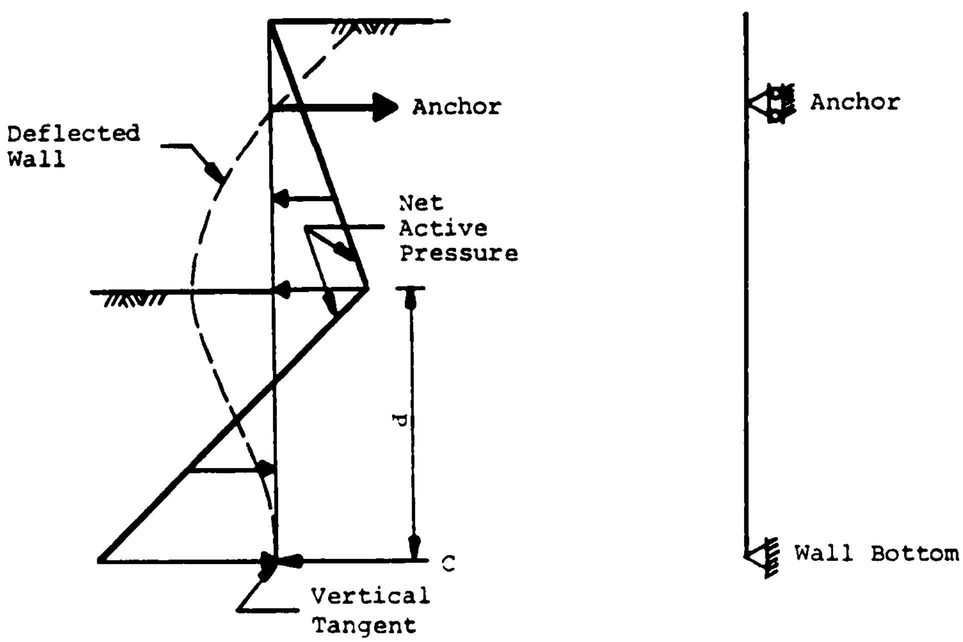
58. In the structural analysis for the equivalent beam method, bending moments, shears, and deflections are determined from a beam analysis of the wall with simple supports at the anchor and at the zero pressure point.

59. Fixed earth (Terzaghi 1943) method. The wall is subjected to net active pressure (Figure 9a) and is analyzed as a beam on simple supports at the anchor and at the wall bottom (Figure 9b). Design penetration is determined when the tangent to the deflected wall at the bottom is vertical.

60. No additional structural analysis for this method is necessary since bending moments, shears, and deflections are calculated during determination of design penetration.

Structural Analysis Procedure

61. A one-dimensional finite element procedure (Dawkins 1982) for linearly elastic prismatic beams is used to perform the structural analysis of each type of wall. The nodes of the finite element model are located at the calculation points described previously and supports are applied as described for each design method.



a. Design pressure

b. Supports for design and analysis

Figure 9. Anchored wall design by fixed earth (Terzaghi 1943) method

PART V: COMPUTER PROGRAM

62. The computer program, CWALSHT, which implements the procedures described in paragraphs 48 through 61, is written in the FORTRAN language for interactive operations from a remote terminal. All arithmetic operations are performed in single precision. For computer systems employing fewer than 15 significant figures for real numbers, it may be necessary to perform some operations in double precision.

Input Data

63. Input data may be provided interactively either from the user's terminal or from a previously prepared data file. When data are input from the terminal during execution, the program provides prompting messages to indicate the type and amount of input data to be entered. The characteristics of a previously prepared data file are described in the Guide for Data Input contained in Appendix A.

64. Whenever an input sequence is completed, either from a data file or from the user's terminal, the program provides an opportunity to change any or all parts of the input data in an editing mode.

65. Whenever any input data are entered from the user's terminal, the program provides for saving the existing input data in a permanent file.

Output Data

66. The user has several options regarding the amount and destination of the output from the program. The four basic parts of the output and user option pertaining to each part are described in paragraphs 67 through 70. Each part may be directed to the user's terminal, to an output file, or to both simultaneously.

Echoprint of input data

67. A complete tabulation of all input data as read from the user terminal or from an input file. The user may elect to omit the echoprint.

Soil pressures for design

68. A tabulation of the active and passive pressures on each side of the wall and the combined net active (and net passive, if required) pressure down to a depth equal to three times the exposed height of the wall. If the

"automatic" seepage option has been selected, these pressures correspond to the initial trial seepage gradient. This section of the output is not available in the Analysis mode. Also, this section of the output may be omitted.

Summary of results

69. A tabulation of design penetration from the Design mode or the factor of safety from the Analysis mode with maximum bending moment and deflection for a cantilever wall; or a tabulation of design penetration or factor of safety, maximum bending moment and deflection, and anchor force for each method for an anchored wall. This summary may be directed to an output file, to the user's terminal, or both.

Complete results

70. A complete tabulation of the elevation, bending moment, shear force, deflection, and final net pressure at each calculation point on the wall. Whenever dual values exist at a single point (e.g., discontinuities in soil pressures in stratified soils or sudden changes in shear at the anchor or at points of application of horizontal line loads), two lines of results appear for that point giving the values immediately above and below the discontinuity. The user may omit this section of the output, direct it to the terminal, or write it to the output file containing the summary of results. For anchored walls the user may elect to output the complete tabulation of results for any or all of the design methods exercised. The final soil pressures associated with the Analysis or Design may be included as a part of this section or may be omitted.

Graphics Display of Input Data

71. Portrayal of input data may consist of three parts:

a. Input geometry. A plot of all structure, soil profile, and water elevations including a summary of soil layer properties. The user is allowed to select vertical and horizontal limits for the display. Unless the limits provided define a square area, this plot of the geometry of the system will be distorted.

b. Input surface surcharges. A schematic displaying all surcharge loads applied to the soil surface on each side of the wall if surcharges are present.

c. Input horizontal loads. A schematic of concentrated horizontal line loads and horizontal distributed loads applied to the wall if horizontal loads are present.

Graphics Display of Design Soil Pressures

72. Two plots of (initial) Design soil pressures are available for elevations from the top of the wall down to a depth equal to three times the exposed height of the wall:

a. Net active (and passive, if necessary) soil pressures.

b. Active and passive pressures on each side of the wall.

Graphics Display of Results

73. Five plots of results are available consisting of: bending moments, shear forces, (scaled) deflections, net pressures, and (optional) final active and passive soil pressures on each side of the wall.

Units and Sign Conventions

74. Units and sign conventions for forces and displacements used for calculations and output of results are shown in Table 1.

Table 1

Units and Sign Conventions

Item	Unit	Sign Convention
Horizontal distances	FT	Always positive
Elevations	FT	Positive or negative decreasing downward
Modulus of elasticity	PSI	
Wall moment of inertia	$IN.^4$	
Soil unit weight	PCF	
Angle of internal friction	DEG	
Cohesion	PSF	
Angle of wall friction	DEG	Positive or negative
Horizontal line loads	PLF	Positive to left
Horizontal applied pressures	PSF	Positive to left
Vertical line surcharges	PLF	Positive downward
Strip, ramp, triangular, variable or uniform surcharges	PSF	Positive downward
Water unit weight	PCF	
Earthquake acceleration	G's	Always positive
Pressures	PSF	Positive to left
Bending moment	LB-FT/FT	Positive if produces compression on left side of wall
Shear force	LB/FT	Positive acts to left on top end of vertical wall section
Deflection	IN.	Positive to left
"Scaled" deflection	$LB\text{-}IN.^3$	Positive to left
Anchor force	LB/FT	Always tension

PART VI: EXAMPLE SOLUTIONS

75. Numerous wall/soil systems have been investigated to test and verify the computational processes used in the program. The example solutions presented below are intended to illustrate the operation of the program and are not to be interpreted as recommendations for its application.

Cantilever Walls

Example CANT1

76. The cantilever retaining wall shown in Figure 10 was designed for a factor of safety of 1.5 for both active and passive effects. Initiation of

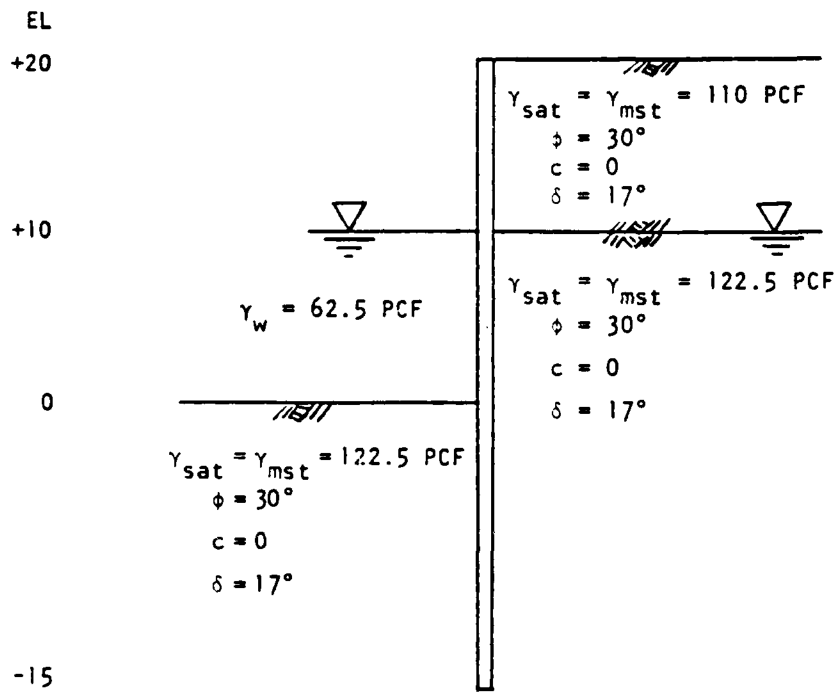


Figure 10. System for Example CANT1

the program and entry of input data from the terminal are shown in Figure 11. An echoprint of input data is given in Figure 12. The data entered from the terminal were saved in the input file format. The input file generated by the program is shown in Figure 13. A plot of the structure geometry is presented in Figure 14. Soil pressures to be used in the design are tabulated in Figure 15 and shown graphically in Figure 16. Note that the user may discontinue the solution after input data have been echoprinted and/or plotted and after the design soil pressures have been printed and/or plotted. If the

```
     PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                                   BY CLASSICAL METHODS
     DATE: 08/21/89                                                  TIME: 1:18:09

     ARE INPUT DATA TO BE READ FROM YOUR TERMINAL OR A FILE?
     ENTER 'TERMINAL' OR 'FILE'.
 ? t
     ENTER NUMBER OF HEADING LINES (1 TO 4).
 ? 2
     ENTER 2 HEADING LINE(S).
 ? cantilever retaining wall in granular soil
 ? design for fs = 1.5 on both active and passive
     ENTER WALL TYPE: 'CANTILEVER' OR 'ANCHORED'.
 ? c
     ENTER MODE: 'DESIGN' OR 'ANALYSIS'.
 ? d
     ENTER LEVEL 1 FACTORS OF SAFETY FOR DESIGN FOR
         ACTIVE PRESSURE     PASSIVE PRESSURE
 ? 1.5 1.5
     ENTER ELEVATION AT TOP OF WALL (FT).
 ? 20
     ENTER NUMBER OF RIGHTSIDE SURFACE POINTS (1 TO 21).
 ? 1
     ENTER  1 RIGHTSIDE SURFACE POINTS, ONE POINT AT A TIME.

         DISTANCE FROM     ELEVATION
           WALL (FT)          (FT)
 ? 0 20
     ARE LEFTSIDE AND RIGHTSIDE SURFACES SYMMETRIC?
     ENTER 'YES' OR 'NO'.
 ? n
     ENTER NUMBER OF  LEFTSIDE SURFACE POINTS (1 TO 21).
 ? 1
     ENTER  1  LEFTSIDE SURFACE POINTS, ONE POINT AT A TIME.

         DISTANCE FROM     ELEVATION
           WALL (FT)          (FT)
 ? 0 0
     ARE SOIL STRENGTHS OR ACTIVE AND PASSIVE COEFFICIENTS TO BE
     PROVIDED FOR RIGHTSIDE SOIL?
     ENTER 'STRENGTHS' OR 'COEFFICIENTS'.
 ? s
     ENTER LEVEL 2 FACTOR OF SAFETY FOR RIGHTSIDE SOIL ACTIVE  PRESSURES.
     ENTER 'DEFAULT' IF LEVEL 1 FACTOR APPLIES.
 ? d
     ENTER LEVEL 2 FACTOR OF SAFETY FOR RIGHTSIDE SOIL PASSIVE PRESSURES.
     ENTER 'DEFAULT' IF LEVEL 1 FACTOR APPLIES.
 ? d
     ENTER NUMBER OF RIGHTSIDE SOIL LAYERS (1 TO 15).
 ? 2
```

Figure 11. Terminal input for Example CANT1 (Sheet 1 of 3)

```
    ENTER DATA FOR  2 RIGHTSIDE SOIL LAYERS, ONE LINE PER LAYER.
      (OMIT LAYER BOTTOM ELEVATION AND SLOPE FOR LAST LAYER.)
      (ENTER 'DEFAULT' FOR EITHER FACTOR OF SAFETY IF LEVEL 2 FACTOR APPLIES.)
      (OMIT PASSIVE FACTOR OF SAFETY IF MODE IS ANALYSIS.)

                  ANGLE OF          ANGLE OF  WALL                      <-FACTOR OF->
  SAT.    MOIST   INTERNAL  COH-      WALL    ADH-   <--BOTTOM-->     <---SAFETY-->
 WGHT.    WGHT.   FRICTION  ESION   FRICTION  ESION  ELEV.  SLOPE     ACT.     PASS.
 (PCF)    (PCF)     (DEG)   (PSF)     (DEG)   (PSF)  (FT)  (FT/FT)
? 110 110 30 0 17 0 10 0
? 122.5 122.5 30 0 17 0
    ARE LEFTSIDE AND RIGHTSIDE SOIL LAYER DATA SYMMETRIC?
    ENTER 'YES' OR 'NO'.
? n
    ARE SOIL STRENGTHS OR ACTIVE AND PASSIVE COEFFICIENTS TO BE
    PROVIDED FOR  LEFTSIDE SOIL?
    ENTER 'STRENGTHS' OR 'COEFFICIENTS'.
? s
    ENTER LEVEL 2 FACTOR OF SAFETY FOR  LEFTSIDE SOIL ACTIVE  PRESSURES.
    ENTER 'DEFAULT' IF LEVEL 1 FACTOR APPLIES.
? d
    ENTER LEVEL 2 FACTOR OF SAFETY FOR  LEFTSIDE SOIL PASSIVE PRESSURES.
    ENTER 'DEFAULT' IF LEVEL 1 FACTOR APPLIES.
? d
    ENTER NUMBER OF  LEFTSIDE SOIL LAYERS (1 TO 15).
? 1
    ENTER DATA FOR  1  LEFTSIDE SOIL LAYERS, ONE LINE PER LAYER.
      (OMIT LAYER BOTTOM ELEVATION AND SLOPE FOR LAST LAYER.)
      (ENTER 'DEFAULT' FOR EITHER FACTOR OF SAFETY IF LEVEL 2 FACTOR APPLIES.)
      (OMIT PASSIVE FACTOR OF SAFETY IF MODE IS ANALYSIS.)

                  ANGLE OF          ANGLE OF  WALL                      <-FACTOR OF->
  SAT.    MOIST   INTERNAL  COH-      WALL    ADH-   <--BOTTOM-->     <---SAFETY-->
 WGHT.    WGHT.   FRICTION  ESION   FRICTION  ESION  ELEV.  SLOPE     ACT.     PASS.
 (PCF)    (PCF)     (DEG)   (PSF)     (DEG)   (PSF)  (FT)  (FT/FT)
? 122.5 122.5 30 0 17 0
    ARE WATER DATA TO BE PROVIDED?  ENTER 'YES' OR 'NO'.
? y
    ARE WATER DATA TO BE PROVIDED BY ELEVATIONS OR A PRESSURE DISTRIBUTION?
    ENTER 'ELEVATIONS' OR 'PRESSURES'.
? e
    ENTER WATER DATA AS INDICATED.

             WATER        <--WATER ELEVATION-->
          UNIT WEIGHT     RIGHTSIDE    LEFTSIDE
             (PCF)          (FT)         (FT)
? 62.5 10 10
    ARE SURFACE LOADS TO BE APPLIED ON EITHER SIDE?
    ENTER 'YES' OR 'NO'.
? n
    ENTER EARTHQUAKE ACCELERATION (0.0 .LE. EQACC .LT. 1.0 G'S).
? 0
    ENTER NUMBER OF HORIZONTAL LINE LOADS (0 TO 21).
? 0
    ENTER NUMBER OF POINTS FOR HORIZONTAL DISTRIBUTED LOAD DISTRIBUTION
    (0 OR 2 TO 21).
? 0
```

Figure 11. (Sheet 2 of 3)

```
     INPUT COMPLETE.
     DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
     TO A FILE, TO BOTH, OR NEITHER?
     ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? f
     ENTER OUTPUT FILE NAME (6 CHARACTERS MAXIMUM).
? cant1o
     INPUT COMPLETE.
     DO YOU WANT TO EDIT INPUT DATA?
     ENTER 'YES' OR 'NO'.
? n
     DO YOU WANT INPUT DATA SAVED IN A FILE?
     ENTER 'YES' OR 'NO'.
? y
     ENTER FILE NAME FOR SAVING INPUT DATA (6 CHARACTERS MAXIMUM).
? cant1i
     DO YOU WANT TO PLOT INPUT DATA?
     ENTER 'YES' OR 'NO'.
? n
     DO YOU WANT TO CONTINUE WITH THE SOLUTION?
     ENTER 'YES' OR 'NO'.
? y
     DO YOU WANT A LISTING OF SOIL PRESSURES
     BEFORE CONTINUING WITH THE DESIGN?
     ENTER 'YES' OR 'NO'.
? y
     DO YOU WANT SOIL PRESSURES PRINTED TO YOUR TERMINAL,
     TO FILE 'CANT1O', OR BOTH?
     ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? f
     DO YOU WANT TO PLOT SOIL PRESSURES?
     ENTER 'YES' OR 'NO'.
? n
     DO YOU WANT TO CONTINUE WITH THE SOLUTION?
     ENTER 'YES' OR 'NO'.
? y
     SOLUTION COMPLETE.
     DO YOU WANT RESULTS PRINTED TO YOUR TERMINAL,
     TO FILE 'CANT1O', OR BOTH?
     ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? f
     DO YOU WANT COMPLETE RESULTS OUTPUT?
     ENTER 'YES' OR 'NO'.
? y
     DO YOU WANT RESULTS TO INCLUDE ACTIVE AND PASSIVE
     EARTH PRESSURES ON EACH SIDE OF THE WALL?
     ENTER 'YES' OR 'NO'.
? y
     DO YOU WANT TO PLOT RESULTS?
     ENTER 'YES' OR 'NO'.
? n
     OUTPUT COMPLETE.
     DO YOU WANT TO EDIT INPUT DATA?
     ENTER 'YES' OR 'NO'.
? n


     INPUT DATA ENTERED FROM TERMINAL.
     LAST INPUT DATA SAVED IN FILE 'CANT1I'.


     OUTPUT SAVED IN FILE 'CANT1O'.


     DO YOU WANT TO MAKE ANOTHER RUN?
     ENTER 'YES' OR 'NO'.
? n


     ********** NORMAL TERMINATION **********
```

Figure 11. (Sheet 3 of 3)

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 08/21/89                                              TIME: 13:23:03
                          ****************
                          *  INPUT DATA  *
                          ****************
I.--HEADING:
  'CANTILEVER RETAINING WALL IN GRANULAR SOIL
  'DESIGN FOR FS = 1.5 ON BOTH ACTIVE AND PASSIVE
II.--CONTROL
  CANTILEVER WALL DESIGN
  LEVEL 1 FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.50
  LEVEL 1 FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.50
III.--WALL DATA
  ELEVATION AT TOP OF WALL    =    20.00 (FT)
IV.--SURFACE POINT DATA
  IV.A--RIGHTSIDE
     DIST. FROM     ELEVATION
     WALL (FT)        (FT)
         0.00         20.00
  IV.B-- LEFTSIDE
     DIST. FROM     ELEVATION
     WALL (FT)        (FT)
         0.00          0.00
V.--SOIL LAYER DATA
  V.A.--RIGHTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT

                ANGLE OF           ANGLE OF                          <-SAFETY->
 SAT.    MOIST  INTERNAL   COH-      WALL      ADH-     <--BOTTOM--> <-FACTOR->
WGHT.    WGHT.  FRICTION   ESION   FRICTION    ESION    ELEV.  SLOPE ACT. PASS.
(PCF)    (PCF)   (DEG)     (PSF)    (DEG)      (PSF)    (FT) (FT/FT)
110.00  110.00   30.00      0.0     17.00       0.0     10.00   0.00  DEF  DEF
122.50  122.50   30.00      0.0     17.00       0.0                   DEF  DEF
  V.B.-- LEFTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT

                ANGLE OF           ANGLE OF                          <-SAFETY->
 SAT.    MOIST  INTERNAL   COH-      WALL      ADH-     <--BOTTOM--> <-FACTOR->
WGHT.    WGHT.  FRICTION   ESION   FRICTION    ESION    ELEV.  SLOPE ACT. PASS.
(PCF)    (PCF)   (DEG)     (PSF)    (DEG)      (PSF)    (FT) (FT/FT)
122.50  122.50   30.00      0.0     17.00       0.0                   DEF  DEF
VI.--WATER DATA
     UNIT WEIGHT          =    62.50 (PCF)
     RIGHTSIDE ELEVATION  =    10.00 (FT)
      LEFTSIDE ELEVATION  =    10.00 (FT)
     NO SEEPAGE
VII.--SURFACE LOADS
     NONE
VIII.--HORIZONTAL LOADS
     NONE
```

Figure 12. Echoprint of input data for Example CANT1

```
1000 'CANTILEVER RETAINING WALL IN GRANULAR SOIL
1010 'DESIGN FOR FS = 1.5 ON BOTH ACTIVE AND PASSIVE
1020 CONTROL  C  D    1.50     1.50
1030 WALL       20.00
1040 SURFACE RIGHTSIDE   1
1050      0.00     20.00
1060 SURFACE  LEFTSIDE   1
1070      0.00      0.00
1080 SOIL RIGHTSIDE  STRENGTH    2    0.00     0.00
1090  110.00  110.00 30.00    0.00  17.00     0.00     10.00    0.00 0.00 0.00
1100  122.50  122.50 30.00    0.00  17.00     0.00      0.00    0.00
1110 SOIL  LEFTSIDE  STRENGTH    1    0.00     0.00
1120  122.50  122.50 30.00    0.00  17.00     0.00      0.00    0.00
1130 WATER ELEVATIONS    62.50   10.00   10.00
1140 FINISH
```

Figure 13. Input file for Example CANT1

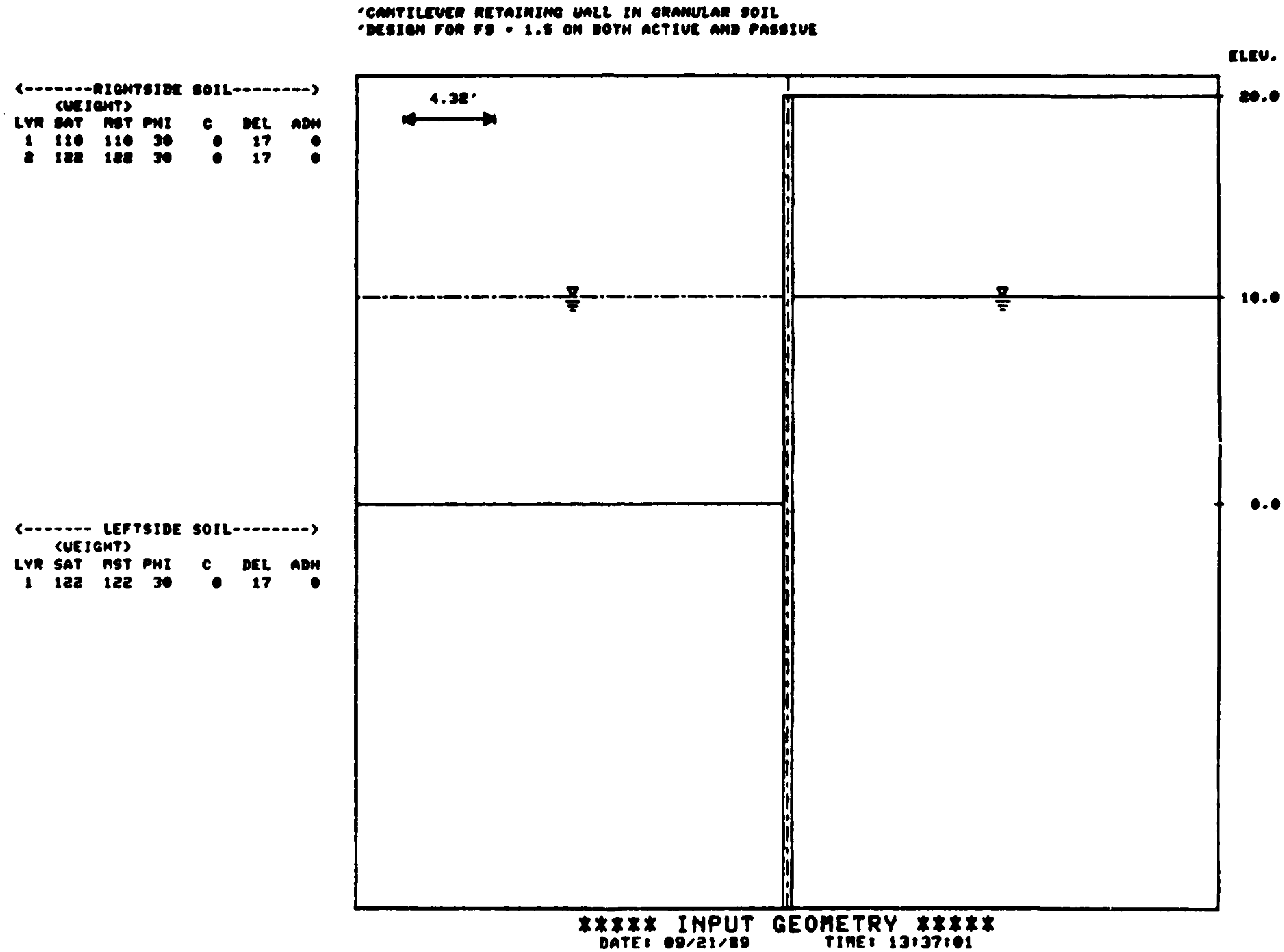


Figure 14. Input geometry plot for Example CANT1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/21/89 TIME: 13:23:34

```
****************************
*    SOIL PRESSURES FOR    *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING

'CANTILEVER RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS = 1.5 ON BOTH ACTIVE AND PASSIVE

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

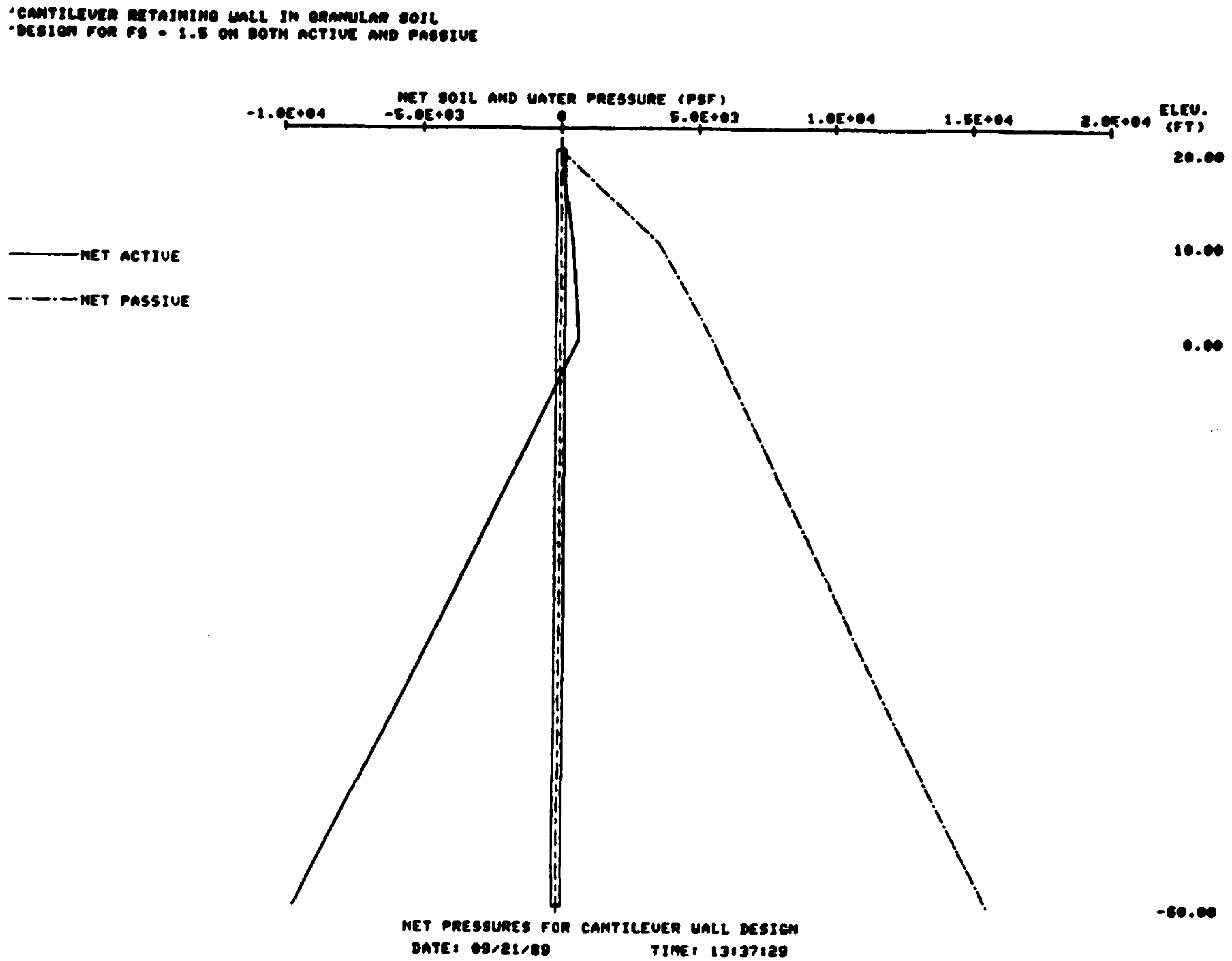
LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

	<-LEFTSIDE PRESSURES->		<---NET PRESSURES----> (SOIL PLUS WATER)		<RIGHTSIDE PRESSURES->	
ELEV. (FT)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
20.00	0.	0.	0.	0.	0.	0.
19.00	0.	0.	4.367E+01	3.559E+02	4.367E+01	3.559E+02
18.00	0.	0.	8.734E+01	7.118E+02	8.734E+01	7.118E+02
17.00	0.	0.	1.310E+02	1.068E+03	1.310E+02	1.068E+03
16.00	0.	0.	1.747E+02	1.424E+03	1.747E+02	1.424E+03
15.00	0.	0.	2.184E+02	1.780E+03	2.184E+02	1.780E+03
14.00	0.	0.	2.620E+02	2.135E+03	2.620E+02	2.135E+03
13.00	0.	0.	3.057E+02	2.491E+03	3.057E+02	2.491E+03
12.00	0.	0.	3.494E+02	2.847E+03	3.494E+02	2.847E+03
11.00	0.	0.	3.930E+02	3.203E+03	3.930E+02	3.203E+03
10.00	0.	0.	4.367E+02	3.559E+03	4.367E+02	3.559E+03
9.00	0.	0.	4.605E+02	3.753E+03	4.605E+02	3.753E+03
8.00	0.	0.	4.843E+02	3.947E+03	4.843E+02	3.947E+03
7.00	0.	0.	5.082E+02	4.142E+03	5.082E+02	4.142E+03
6.00	0.	0.	5.320E+02	4.336E+03	5.320E+02	4.336E+03
5.00	0.	0.	5.558E+02	4.530E+03	5.558E+02	4.530E+03
4.00	0.	0.	5.796E+02	4.724E+03	5.796E+02	4.724E+03
3.00	0.	0.	6.034E+02	4.918E+03	6.034E+02	4.918E+03
2.00	0.	0.	6.273E+02	5.112E+03	6.273E+02	5.112E+03
1.00	0.	0.	6.511E+02	5.306E+03	6.511E+02	5.306E+03
0.00	0.	0.	6.749E+02	5.500E+03	6.749E+02	5.500E+03
-1.00	1.941E+02	2.382E+01	5.046E+02	5.671E+03	6.987E+02	5.695E+03
-2.00	3.883E+02	4.764E+01	3.343E+02	5.841E+03	7.225E+02	5.889E+03
-3.00	5.824E+02	7.146E+01	1.640E+02	6.011E+03	7.464E+02	6.083E+03
-3.96	7.693E+02	9.439E+01	0.	6.175E+03	7.693E+02	6.270E+03
-4.00	7.765E+02	9.528E+01	-6.354E+00	6.182E+03	7.702E+02	6.277E+03
-5.00	9.707E+02	1.191E+02	-1.767E+02	6.352E+03	7.940E+02	6.471E+03
-6.00	1.165E+03	1.429E+02	-3.470E+02	6.522E+03	8.178E+02	6.665E+03
-7.00	1.359E+03	1.667E+02	-5.173E+02	6.693E+03	8.416E+02	6.859E+03
-8.00	1.553E+03	1.906E+02	-6.876E+02	6.863E+03	8.655E+02	7.054E+03
-9.00	1.747E+03	2.144E+02	-8.579E+02	7.033E+03	8.893E+02	7.248E+03
-10.00	1.941E+03	2.382E+02	-1.028E+03	7.204E+03	9.131E+02	7.442E+03

Figure 15. Tabulated initial soil pressures for Example CANT1 (Continued)

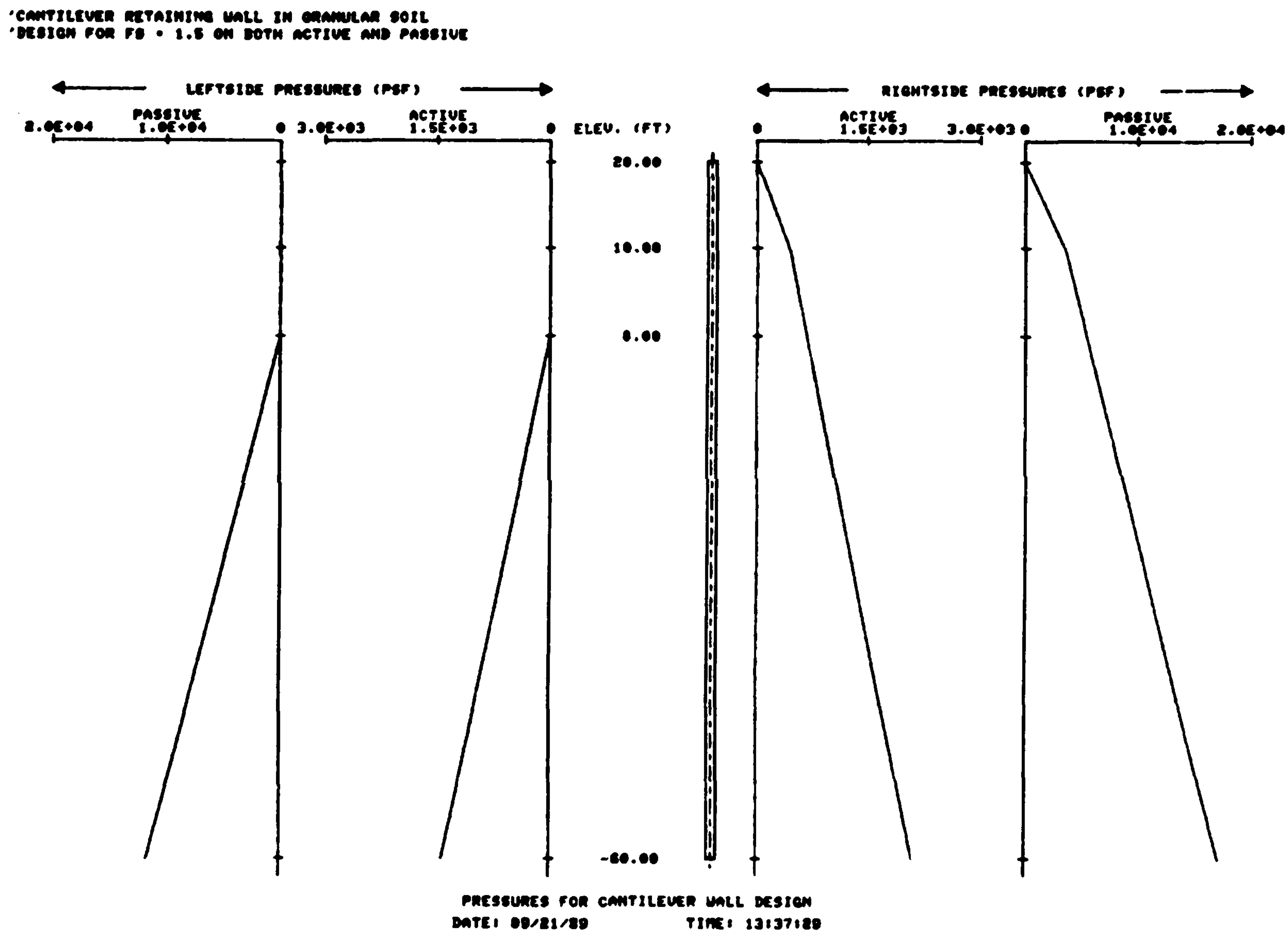
-11.00	2.135E+03	2.620E+02	-1.199E+03	7.374E+03	9.369E+02	7.636E+03
-12.00	2.330E+03	2.858E+02	-1.369E+03	7.544E+03	9.607E+02	7.830E+03
-13.00	2.524E+03	3.097E+02	-1.539E+03	7.715E+03	9.846E+02	8.024E+03
-14.00	2.718E+03	3.335E+02	-1.709E+03	7.885E+03	1.008E+03	8.218E+03
-15.00	2.912E+03	3.573E+02	-1.880E+03	8.055E+03	1.032E+03	8.412E+03
-16.00	3.106E+03	3.811E+02	-2.050E+03	8.225E+03	1.056E+03	8.607E+03
-17.00	3.300E+03	4.049E+02	-2.220E+03	8.396E+03	1.080E+03	8.801E+03
-18.00	3.494E+03	4.288E+02	-2.391E+03	8.566E+03	1.104E+03	8.995E+03
-19.00	3.689E+03	4.526E+02	-2.561E+03	8.736E+03	1.127E+03	9.189E+03
-20.00	3.883E+03	4.764E+02	-2.731E+03	8.907E+03	1.151E+03	9.383E+03
-21.00	4.077E+03	5.002E+02	-2.902E+03	9.077E+03	1.175E+03	9.577E+03
-22.00	4.271E+03	5.240E+02	-3.072E+03	9.247E+03	1.199E+03	9.771E+03
-23.00	4.465E+03	5.479E+02	-3.242E+03	9.418E+03	1.223E+03	9.966E+03
-24.00	4.659E+03	5.717E+02	-3.413E+03	9.588E+03	1.247E+03	1.016E+04
-25.00	4.853E+03	5.955E+02	-3.583E+03	9.758E+03	1.270E+03	1.035E+04
-26.00	5.047E+03	6.193E+02	-3.753E+03	9.929E+03	1.294E+03	1.055E+04
-27.00	5.242E+03	6.431E+02	-3.924E+03	1.010E+04	1.318E+03	1.074E+04
-28.00	5.436E+03	6.670E+02	-4.094E+03	1.027E+04	1.342E+03	1.094E+04
-29.00	5.630E+03	6.908E+02	-4.264E+03	1.044E+04	1.366E+03	1.113E+04
-30.00	5.824E+03	7.146E+02	-4.435E+03	1.061E+04	1.390E+03	1.132E+04
-31.00	6.018E+03	7.384E+02	-4.605E+03	1.078E+04	1.413E+03	1.152E+04
-32.00	6.212E+03	7.622E+02	-4.775E+03	1.095E+04	1.437E+03	1.171E+04
-33.00	6.406E+03	7.861E+02	-4.945E+03	1.112E+04	1.461E+03	1.191E+04
-34.00	6.601E+03	8.099E+02	-5.116E+03	1.129E+04	1.485E+03	1.210E+04
-35.00	6.795E+03	8.337E+02	-5.286E+03	1.146E+04	1.509E+03	1.230E+04
-36.00	6.989E+03	8.575E+02	-5.456E+03	1.163E+04	1.532E+03	1.249E+04
-37.00	7.183E+03	8.813E+02	-5.627E+03	1.180E+04	1.556E+03	1.268E+04
-38.00	7.377E+03	9.052E+02	-5.797E+03	1.197E+04	1.580E+03	1.288E+04
-39.00	7.571E+03	9.290E+02	-5.967E+03	1.214E+04	1.604E+03	1.307E+04
-40.00	7.765E+03	9.528E+02	-6.138E+03	1.231E+04	1.628E+03	1.327E+04
-41.00	7.960E+03	9.766E+02	-6.308E+03	1.248E+04	1.652E+03	1.346E+04
-42.00	8.154E+03	1.000E+03	-6.478E+03	1.265E+04	1.675E+03	1.365E+04
-43.00	8.348E+03	1.024E+03	-6.649E+03	1.282E+04	1.699E+03	1.385E+04
-44.00	8.542E+03	1.048E+03	-6.819E+03	1.299E+04	1.723E+03	1.404E+04
-45.00	8.736E+03	1.072E+03	-6.989E+03	1.316E+04	1.747E+03	1.424E+04
-46.00	8.930E+03	1.096E+03	-7.160E+03	1.333E+04	1.771E+03	1.443E+04
-47.00	9.124E+03	1.120E+03	-7.330E+03	1.351E+04	1.794E+03	1.462E+04
-48.00	9.318E+03	1.143E+03	-7.500E+03	1.368E+04	1.818E+03	1.482E+04
-49.00	9.513E+03	1.167E+03	-7.670E+03	1.385E+04	1.842E+03	1.501E+04
-50.00	9.707E+03	1.191E+03	-7.841E+03	1.402E+04	1.866E+03	1.521E+04
-51.00	9.901E+03	1.215E+03	-8.011E+03	1.419E+04	1.890E+03	1.540E+04
-52.00	1.009E+04	1.239E+03	-8.181E+03	1.436E+04	1.914E+03	1.560E+04
-53.00	1.029E+04	1.262E+03	-8.352E+03	1.453E+04	1.937E+03	1.579E+04
-54.00	1.048E+04	1.286E+03	-8.522E+03	1.470E+04	1.961E+03	1.598E+04
-55.00	1.068E+04	1.310E+03	-8.692E+03	1.487E+04	1.985E+03	1.618E+04
-56.00	1.087E+04	1.334E+03	-8.863E+03	1.504E+04	2.009E+03	1.637E+04
-57.00	1.107E+04	1.358E+03	-9.033E+03	1.521E+04	2.033E+03	1.657E+04
-58.00	1.126E+04	1.382E+03	-9.203E+03	1.538E+04	2.056E+03	1.676E+04
-59.00	1.145E+04	1.405E+03	-9.374E+03	1.555E+04	2.080E+03	1.695E+04
-60.00	1.165E+04	1.429E+03	-9.544E+03	1.572E+04	2.104E+03	1.715E+04
-61.00	1.184E+04	1.453E+03	-9.714E+03	1.589E+04	2.128E+03	1.734E+04

Figure 15. (Concluded)



a. Initial net pressures

Figure 16. Program plots of initial soil pressures for Example CANT1 (Continued)



b. Active and passive pressures

Figure 16. (Concluded)

solution is discontinued, the user has the opportunity to edit existing input data, restart the program, or terminate execution of the program.

77. The summary of results is presented in Figure 17. Optional complete resulted are tabulated in Figure 18. Two lines of data will appear for any elevation at which a discontinuity in shear force or soil pressure occurs. Optional final design soil pressures are tabulated in Figure 19. Unless the automatic seepage option has been invoked, the final design soil pressures will be the same as the initial pressures. Graphical presentations of the results are shown in Figures 20 through 24.

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 08/21/89                                              TIME: 13:24:00

                    *****************************
                    *  SUMMARY OF RESULTS FOR   *
                    *  CANTILEVER WALL DESIGN   *
                    *****************************

I.--HEADING

  'CANTILEVER RETAINING WALL IN GRANULAR SOIL
  'DESIGN FOR FS = 1.5 ON BOTH ACTIVE AND PASSIVE

II.--SUMMARY


     RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

      LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

WALL BOTTOM ELEV. (FT)     :        -27.53
      PENETRATION (FT)     :         27.53

MAX. BEND. MOMENT (LB-FT) :       151550.
      AT ELEVATION (FT)    :        -14.00

MAX. SCALED DEFL. (LB-IN3):    1.6666E+11
      AT ELEVATION (FT)    :         20.00

     (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
     ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
     IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)
```

Figure 17. Summary of results for Example CANT1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/21/89 TIME: 13:24:00

****
* COMPLETE RESULTS FOR *
* CANTILEVER WALL DESIGN *
****

I.--HEADING

'CANTILEVER RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS = 1.5 ON BOTH ACTIVE AND PASSIVE

III.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
20.00	0.	0.	1.6666E+11	0.00
19.00	7.	22.	1.6132E+11	43.67
18.00	58.	87.	1.5598E+11	87.34
17.00	197.	197.	1.5064E+11	131.01
16.00	466.	349.	1.4530E+11	174.68
15.00	910.	546.	1.3996E+11	218.35
14.00	1572.	786.	1.3462E+11	262.02
13.00	2496.	1070.	1.2928E+11	305.69
12.00	3727.	1397.	1.2395E+11	349.36
11.00	5306.	1769.	1.1863E+11	393.03
10.00	7278.	2184.	1.1331E+11	436.70
9.00	9684.	2632.	1.0801E+11	460.52
8.00	12551.	3105.	1.0272E+11	484.34
7.00	15901.	3601.	9.7457E+10	508.16
6.00	19760.	4121.	9.2220E+10	531.98
5.00	24151.	4665.	8.7017E+10	555.80
4.00	29098.	5232.	8.1856E+10	579.62
3.00	34624.	5824.	7.6745E+10	603.44
2.00	40754.	6439.	7.1694E+10	627.26
1.00	47511.	7079.	6.6714E+10	651.08
0.00	54919.	7742.	6.1816E+10	674.90
-1.00	62969.	8331.	5.7013E+10	504.59
-2.00	71524.	8751.	5.2319E+10	334.27
-3.00	80414.	9000.	4.7748E+10	163.96
-3.96	89129.	9079.	4.3479E+10	0.00
-4.00	89467.	9079.	4.3316E+10	-6.35
-5.00	98514.	8987.	3.9039E+10	-176.67
-6.00	107385.	8725.	3.4933E+10	-346.98
-7.00	115908.	8293.	3.1011E+10	-517.30
-8.00	123914.	7691.	2.7290E+10	-687.61
-9.00	131233.	6918.	2.3783E+10	-857.92
-10.00	137693.	5975.	2.0503E+10	-1028.24
-11.00	143126.	4861.	1.7460E+10	-1198.55
-12.00	147360.	3578.	1.4665E+10	-1368.87

Figure 18. Complete results for Example CANT1 (Continued)

-13.00	150225.	2124.	1.2124E+10	-1539.18
-14.00	151550.	499.	9.8421E+09	-1709.50
-15.00	151167.	-1295.	7.8221E+09	-1879.81
-16.00	148903.	-3260.	6.0630E+09	-2050.12
-17.00	144589.	-5396.	4.5609E+09	-2220.44
-18.00	138055.	-7701.	3.3084E+09	-2390.75
-19.00	129130.	-10177.	2.2941E+09	-2561.07
-20.00	117644.	-12823.	1.5025E+09	-2731.38
-21.00	103427.	-15640.	9.1386E+08	-2901.70
-22.00	86308.	-18627.	5.0351E+08	-3072.01
-22.15	83475.	-19090.	4.5549E+08	-3097.60
-23.00	66387.	-20831.	2.4187E+08	-1000.21
-24.00	45467.	-20597.	9.4807E+07	1468.03
-25.00	26015.	-17895.	2.6521E+07	3936.26
-26.00	10499.	-12725.	3.7571E+06	6404.49
-27.00	1388.	-5086.	5.7951E+04	8872.73
-27.53	-0.	0.	0.	10189.84

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 18. (Concluded)

IV.--SOIL PRESSURES

ELEVATION	< LEFTSIDE PRESSURE (PSF)>		<RIGHTSIDE PRESSURE (PSF)>	
(FT)	PASSIVE	ACTIVE	ACTIVE	PASSIVE
20.00	0.	0.	0.	0.
19.00	0.	0.	44.	356.
18.00	0.	0.	87.	712.
17.00	0.	0.	131.	1068.
16.00	0.	0.	175.	1424.
15.00	0.	0.	218.	1780.
14.00	0.	0.	262.	2135.
13.00	0.	0.	306.	2491.
12.00	0.	0.	349.	2847.
11.00	0.	0.	393.	3203.
10.00	0.	0.	437.	3559.
9.00	0.	0.	461.	3753.
8.00	0.	0.	484.	3947.
7.00	0.	0.	508.	4142.
6.00	0.	0.	532.	4336.
5.00	0.	0.	556.	4530.
4.00	0.	0.	580.	4724.
3.00	0.	0.	603.	4918.
2.00	0.	0.	627.	5112.
1.00	0.	0.	651.	5306.
0.00	0.	0.	675.	5500.
-1.00	194.	24.	699.	5695.
-2.00	388.	48.	723.	5889.
-3.00	582.	71.	746.	6083.
-3.96	769.	94.	769.	6270.
-4.00	777.	95.	770.	6277.
-5.00	971.	119.	794.	6471.
-6.00	1165.	143.	818.	6665.
-7.00	1359.	167.	842.	6859.
-8.00	1553.	191.	865.	7054.
-9.00	1747.	214.	889.	7248.
-10.00	1941.	238.	913.	7442.
-11.00	2135.	262.	937.	7636.
-12.00	2330.	286.	961.	7830.
-13.00	2524.	310.	985.	8024.
-14.00	2718.	333.	1008.	8218.
-15.00	2912.	357.	1032.	8412.
-16.00	3106.	381.	1056.	8607.
-17.00	3300.	405.	1080.	8801.
-18.00	3494.	429.	1104.	8995.
-19.00	3689.	453.	1127.	9189.
-20.00	3883.	476.	1151.	9383.
-21.00	4077.	500.	1175.	9577.
-22.00	4271.	524.	1199.	9771.
-22.15	4300.	528.	1203.	9801.
-23.00	4465.	548.	1223.	9966.
-24.00	4659.	572.	1247.	10160.
-25.00	4853.	596.	1270.	10354.
-26.00	5047.	619.	1294.	10548.
-27.00	5242.	643.	1318.	10742.
-27.53	5436.	667.	1342.	10936.
-29.00	5630.	691.	1366.	11130.

Figure 19. Final design soil pressures for Example CANT1

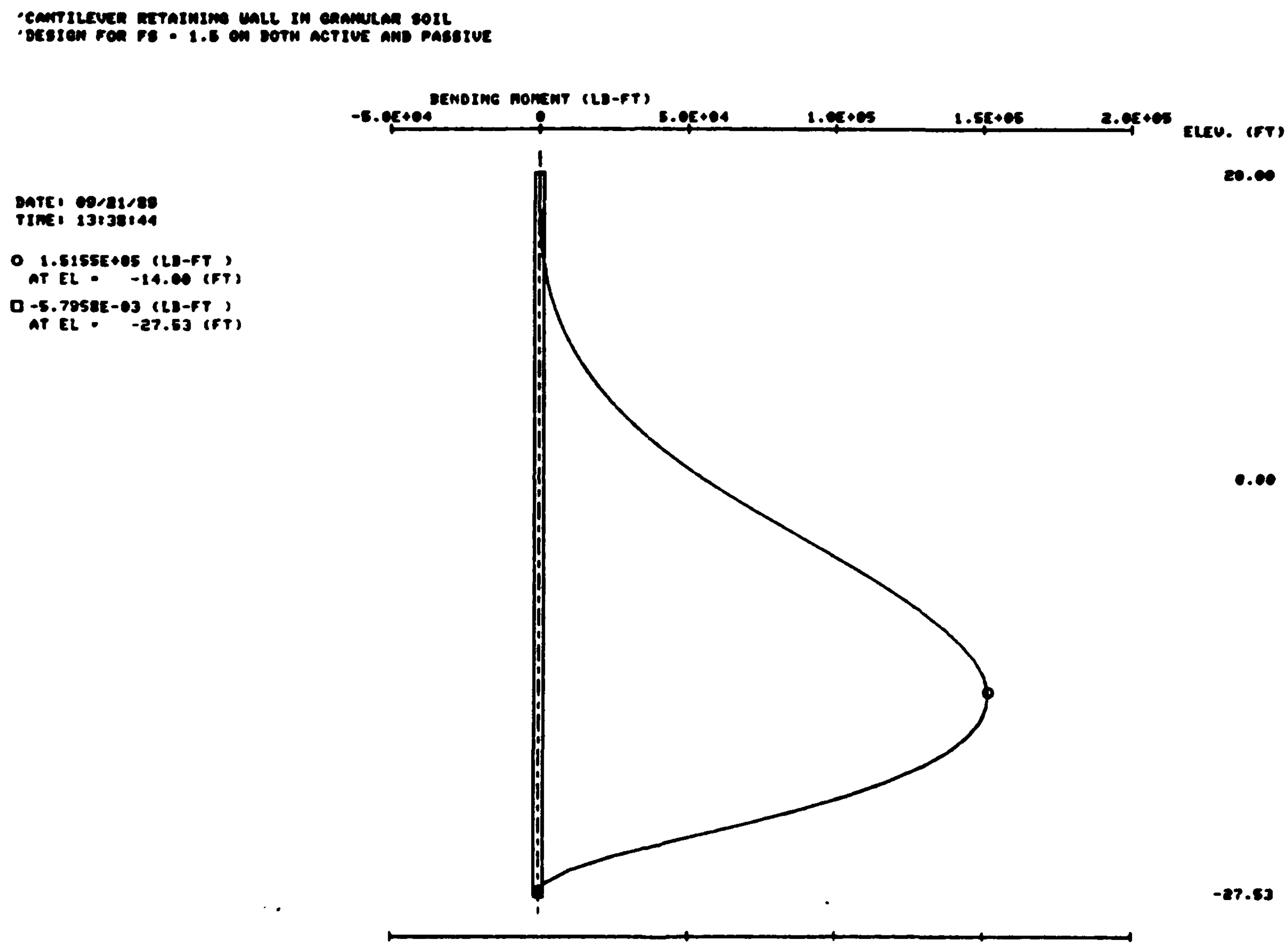


Figure 20. Program plot of bending moment for Example CANT1

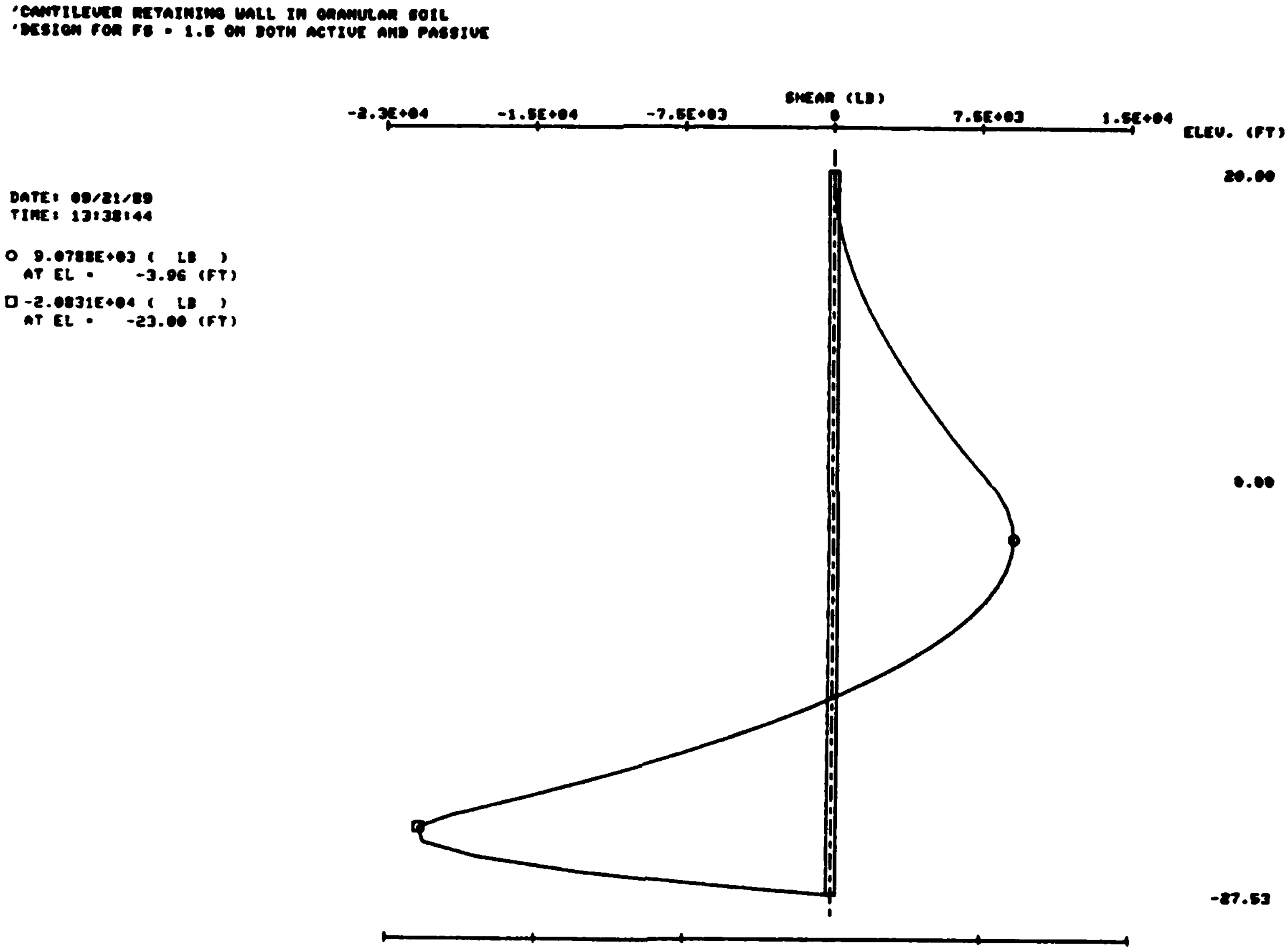


Figure 21. Program plot of shear force for Example CANT1

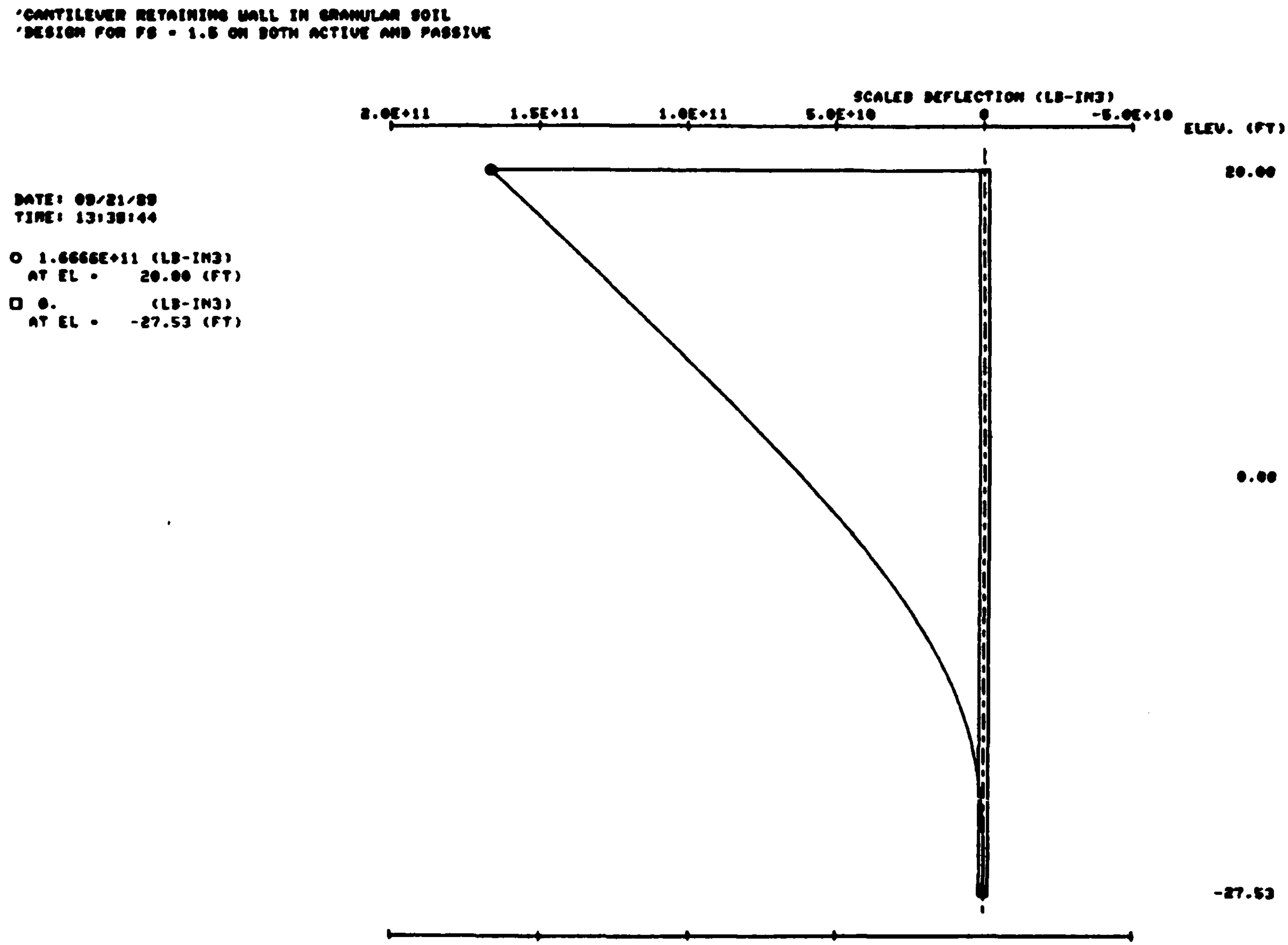


Figure 22. Program plot of scaled deflection for Example CANT1

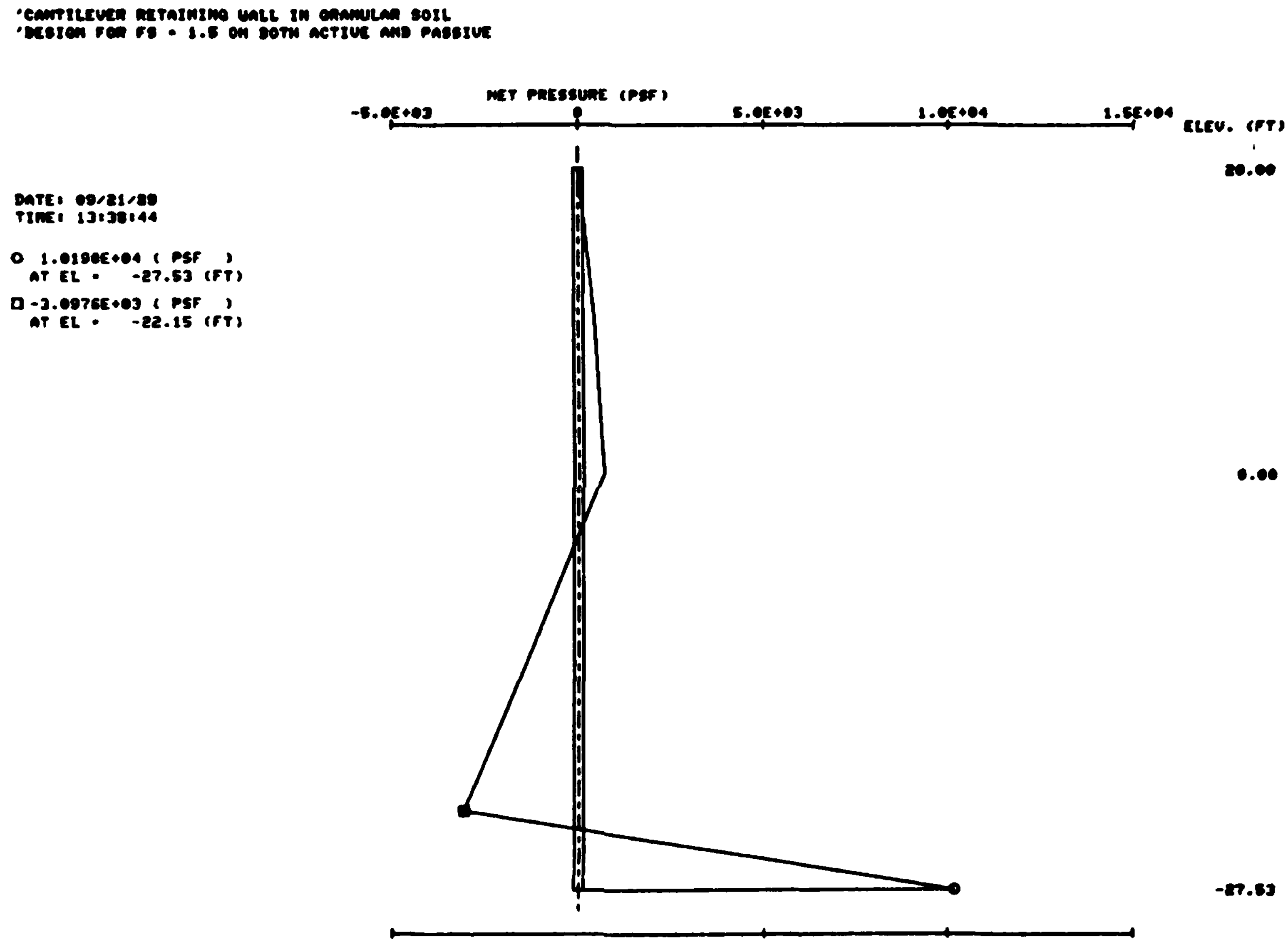


Figure 23. Program plot of design net pressures for Example CANT1

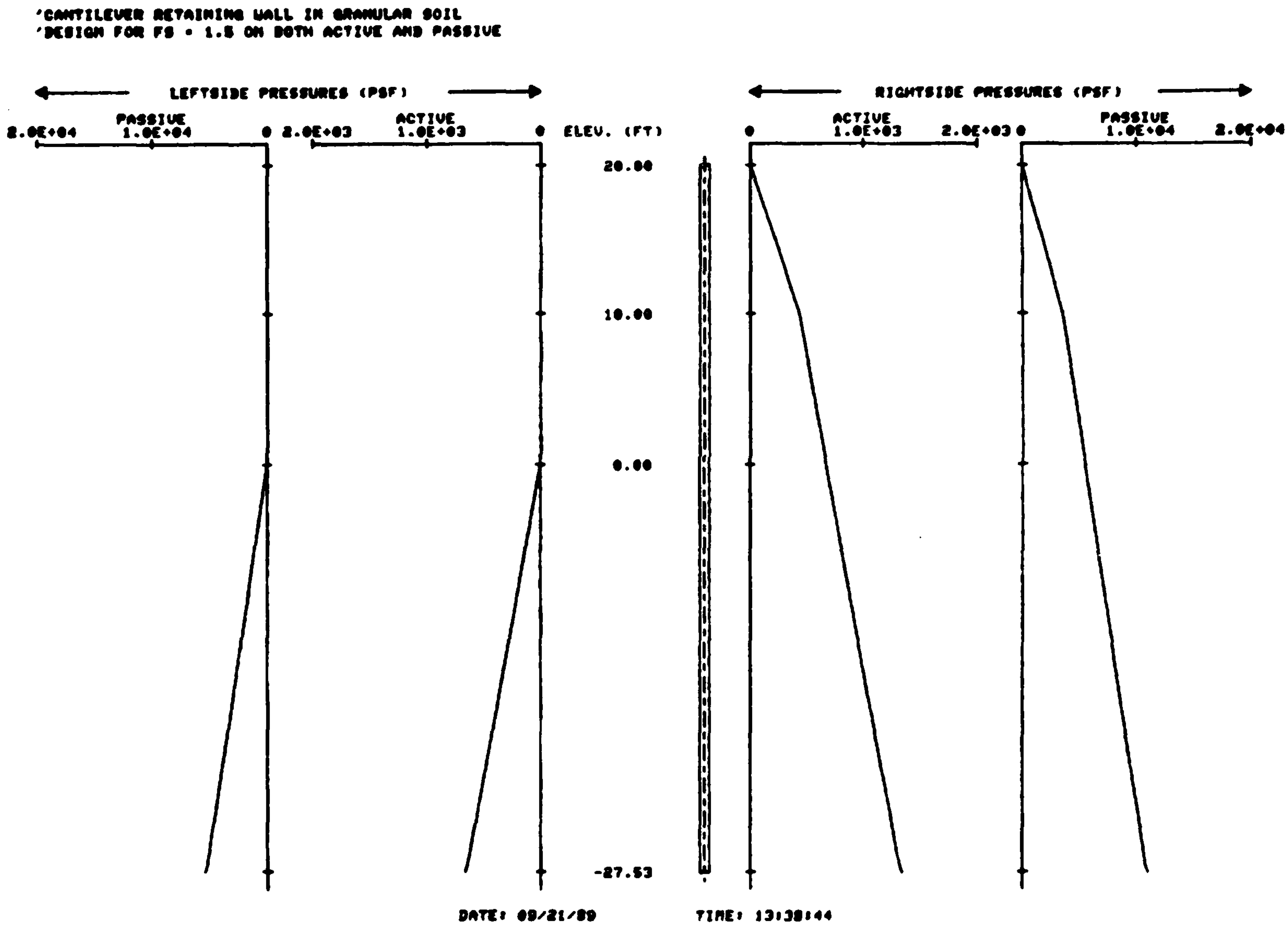


Figure 24. Program plot of final soil pressures for Example CANT1

Example CANT1A

78. The input data for Example CANT1 were edited as shown in Figure 25. The mode of execution was changed from Design to Analysis, and the Analysis was performed for a factor of safety of 1.0 for all active pressures. Even though the Level 1 factor of safety for active pressures is input, all existing Levels 2 and 3 factors for active pressure previously available remain in effect. If it is necessary for Levels 2 and 3 factors to be altered, it will be more efficient to edit the input file externally from the program. In this example, all safety factors for Levels 2 and 3 were previously defaulted to Level 1. The option for factor of safety in this example causes the program to determine a single passive factor of safety applied to all soils on both sides of the wall.

79. The summary of results of the analysis is presented in Figure 26. Other optional results data include a complete tabulation of bending moments, shears, deflections, net pressure, and final design pressures.

```
    PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                               BY CLASSICAL METHODS
    DATE: 08/22/89                                                TIME: 1:14:55

    ARE INPUT DATA TO BE READ FROM YOUR TERMINAL OR A FILE?
    ENTER 'TERMINAL' OR 'FILE'.
? f
    ENTER INPUT FILE NAME (6 CHARACTERS MAXIMUM).
? cant1i
    INPUT COMPLETE.
    DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
    TO A FILE, TO BOTH, OR NEITHER?
    ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? n
    INPUT COMPLETE.
    DO YOU WANT TO EDIT INPUT DATA?
    ENTER 'YES' OR 'NO'.
? y

    MAJOR DATA SECTIONS AND STATUS

         SECTION        CONTENTS              STATUS
         1..............HEADING..............2 LINES
         2..............CONTROL..............CANTILEVER DESIGN
         3..............WALL DATA............FOR DESIGN
         4..............SURFACE DATA.........RIGHTSIDE  1 POINTS
                                             LEFTSIDE   1 POINTS
         5..............SOIL LAYERS..........RIGHTSIDE  2 LAYERS, STRENGTHS
                                             LEFTSIDE   1 LAYERS, STRENGTHS
         6..............WATER................ELEVATIONS AVAILABLE
         7..............VERTICAL LOADS.......NONE
         8..............HORIZONTAL LOADS.....NONE

    ENTER SECTION NUMBER TO BE EDITED, 'STATUS', OR 'FINISHED'.
? 1
    ENTER NUMBER OF HEADING LINES (1 TO 4).
? 2
    ENTER 2 HEADING LINE(S).
? analysis of cantilever retaining wall designed in Example CANT1
? fs = 1 for all active pressures

    ENTER SECTION NUMBER TO BE EDITED, 'STATUS', OR 'FINISHED'.
? 2
    ENTER WALL TYPE: 'CANTILEVER' OR 'ANCHORED'.
? c
    ENTER MODE: 'DESIGN' OR 'ANALYSIS'.
? a
    ENTER FACTOR OF SAFETY OPTION FOR ANALYSIS.
         (1 = SAME FS CALCULATED FOR BOTH ACTIVE AND PASSIVE PRESSURES.
          2 = FS FOR ACTIVE PRESSURES INPUT, FS FOR PASSIVE PRESSURES
              CALCULATED.)
? 2
    ENTER LEVEL 1 FACTOR OF SAFETY FOR ACTIVE PRESSURES.
? 1
```

Figure 25. Editing for Example CANT1A (Continued)

```
    ***************************************************************
    CHANGE IN WALL TYPE OR MODE REQUIRES NEW WALL DATA SECTION.
    ***************************************************************
    ENTER DATA FOR CANTILEVER WALL ANALYSIS.

    ELEV. AT TOP      ELEV. AT WALL      MODULUS OF      MOMENT OF
    OF WALL (FT)       BOTTOM (FT)      ELASTICITY        INERTIA
                                           (PSI)        (IN**4/FT)
? 20 -27.53 2.9e7 280.8

    ENTER SECTION NUMBER TO BE EDITED, 'STATUS', OR 'FINISHED'.
? f
    INPUT COMPLETE.
    DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
    TO A FILE, TO BOTH, OR NEITHER?
    ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
? n
    INPUT COMPLETE.
    DO YOU WANT TO EDIT INPUT DATA?
    ENTER 'YES' OR 'NO'.
? n
    DO YOU WANT INPUT DATA SAVED IN A FILE?
    ENTER 'YES' OR 'NO'.
? n
    DO YOU WANT TO PLOT INPUT DATA?
    ENTER 'YES' OR 'NO'.
? n
    DO YOU WANT TO CONTINUE WITH THE SOLUTION?
    ENTER 'YES' OR 'NO'.
? y
    SOLUTION COMPLETE.
    DO YOU WANT RESULTS PRINTED TO YOUR TERMINAL,
    TO A FILE, OR BOTH?
    ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? t
    DO YOU WANT COMPLETE RESULTS OUTPUT?
    ENTER 'YES' OR 'NO'.
? n
    DO YOU WANT TO PLOT RESULTS?
    ENTER 'YES' OR 'NO'.
? n
    OUTPUT COMPLETE.
    DO YOU WANT TO EDIT INPUT DATA?
    ENTER 'YES' OR 'NO'.
? n


    LAST INPUT FILE PROCESSED = 'CANT1I'.


    DO YOU WANT TO MAKE ANOTHER RUN?
    ENTER 'YES' OR 'NO'.
? n


    ********** NORMAL TERMINATION **********
```

Figure 25. (Concluded)

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                         BY CLASSICAL METHODS
DATE: 08/22/89                                             TIME: 14:18:47

                      ****************************
                      *  SUMMARY OF RESULTS FOR  *
                      * CANTILEVER WALL ANALYSIS *
                      ****************************

I.--HEADING

  'ANALYSIS OF CANTILEVER RETAINING WALL DESIGNED IN
  'FS = 1 FOR ALL ACTIVE PRESSURES

II.--SUMMARY


     RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

      LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

PASSIVE FACTOR OF SAFETY  :        2.27

MAX. BEND. MOMENT (LB-FT) :      109346.
      AT ELEVATION (FT)   :      -14.00

MAXIMUM DEFLECTION (IN)   :   1.4774E+01
      AT ELEVATION (FT)   :        20.00
```

Figure 26. Summary of results for Example CANT1A

Example CANT2

80. The floodwall driven in layered soil shown in Figure 27 was designed for a factor of safety of 1.0 on all soil pressures. The input file for this system is given in Figure 28. The coefficient method for soil pressures produces a discontinuity in soil pressures at el -10 ft* as shown in Figures 29 and 31. The discontinuity has been replaced by an average pressure at el -10 ft, Figures 29 and 30.

81. The summary of results for the design is shown in Figure 32 and the final design pressures are plotted in Figure 33.

---

* All elevations (el) cited herein are in feet referred to National Geodetic Vertical Datum (NGVD) of 1929.

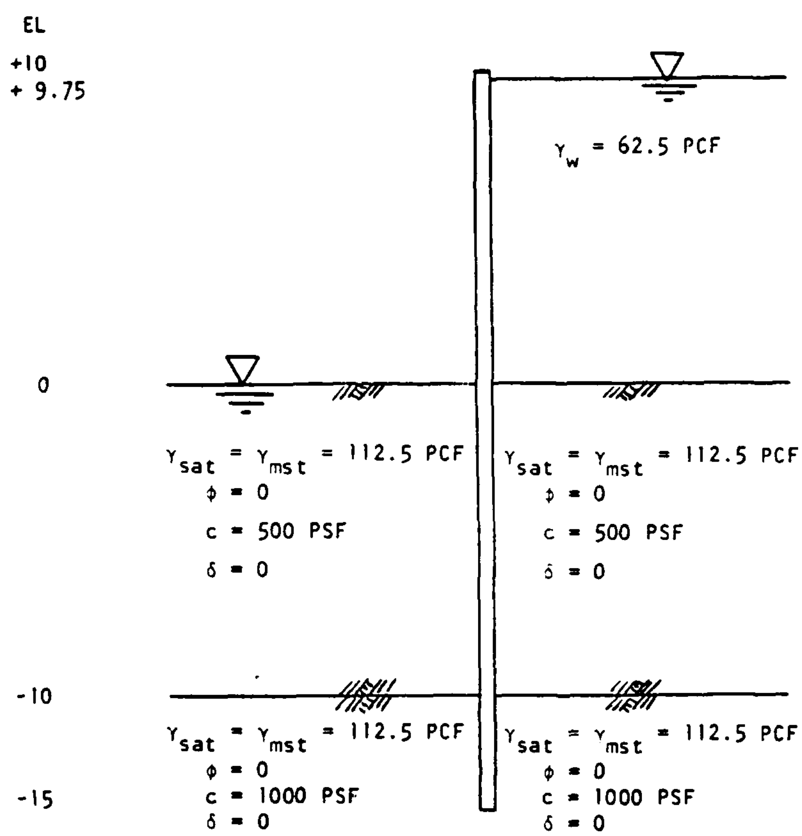


Figure 27. System for Example CANT2

```
1000 'FLOODWALL IN COHESIVE LAYERED SOIL WITH
1010 'HIGH STRENGTH LAYER UNDERLYING WEAKER SOIL
1020 CONTROL  C  D    1.00    1.00
1030 WALL       10.00
1040 SURFACE RIGHTSIDE    1
1050       0.00       0.00
1060 SURFACE  LEFTSIDE    1
1070       0.00       0.00
1080 SOIL RIGHTSIDE  STRENGTH    2    0.00    0.00
1090 112.50 112.50  0 500  0 0 -10  0  0  0
1100 112.50 112.50  0 1000 0  0  0  0
1110 SOIL  LEFTSIDE  STRENGTH    2    0.00    0.00
1120 112.50 112.50  0 500  0 0 -10  0  0  0
1130 112.50 112.50  0 1000 0  0  0  0
1140 WATER ELEVATIONS    62.50    9.75    0.00
1150 FINISH
```

Figure 28. Input file for Example CANT2

PROGRAM CWALSHT - DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/22/89 TIME: 14:50:09

****
* SOIL PRESSURES FOR *
* CANTILEVER WALL DESIGN *
****

I.--HEADING

'FLOODWALL IN COHESIVE LAYERED SOIL WITH

'HIGH STRENGTH LAYER UNDERLYING WEAKER SOIL

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

			<---NET PRESSURES---->			
	<-LEFTSIDE PRESSURES->		(SOIL PLUS WATER)		<RIGHTSIDE PRESSURES->	
ELEV. (FT)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
10.00	0.	0.	0.	0.	0.	0.
9.75	0.	0.	0.	0.	0.	0.
9.00	0.	0.	4.688E+01	4.688E+01	0.	0.
8.00	0.	0.	1.094E+02	1.094E+02	0.	0.
7.00	0.	0.	1.719E+02	1.719E+02	0.	0.
6.00	0.	0.	2.344E+02	2.344E+02	0.	0.
5.00	0.	0.	2.969E+02	2.969E+02	0.	0.
4.00	0.	0.	3.594E+02	3.594E+02	0.	0.
3.00	0.	0.	4.219E+02	4.219E+02	0.	0.
2.00	0.	0.	4.844E+02	4.844E+02	0.	0.
1.00	0.	0.	5.469E+02	5.469E+02	0.	0.
0.00+	0.	0.	6.094E+02	6.094E+02	0.	0.
0.00-	1.000E+03	0.	-3.906E+02	1.609E+03	0.	1.000E+03
-1.00	1.050E+03	0.	-4.406E+02	1.659E+03	0.	1.050E+03
-2.00	1.100E+03	0.	-4.906E+02	1.709E+03	0.	1.100E+03
-3.00	1.150E+03	0.	-5.406E+02	1.759E+03	0.	1.150E+03
-4.00	1.200E+03	0.	-5.906E+02	1.809E+03	0.	1.200E+03
-5.00	1.250E+03	0.	-6.406E+02	1.859E+03	0.	1.250E+03
-6.00	1.300E+03	0.	-6.906E+02	1.909E+03	0.	1.300E+03
-7.00	1.350E+03	0.	-7.406E+02	1.959E+03	0.	1.350E+03
-8.00	1.400E+03	0.	-7.906E+02	2.009E+03	0.	1.400E+03
-9.00	1.450E+03	0.	-8.406E+02	2.059E+03	0.	1.450E+03
-10.00+	1.500E+03	0.	-1.391E+03	2.609E+03	0.	1.500E+03
-10.00-	2.500E+03	0.	-1.391E+03	2.609E+03	0.	2.500E+03

Figure 29. Initial soil pressures for Example CANT2 (Continued)

-11.00	2.550E+03	0.	-1.941E+03	3.159E+03	0.	2.550E+03
-12.00	2.600E+03	0.	-1.991E+03	3.209E+03	0.	2.600E+03
-13.00	2.650E+03	0.	-2.041E+03	3.259E+03	0.	2.650E+03
-14.00	2.700E+03	0.	-2.091E+03	3.309E+03	0.	2.700E+03
-15.00	2.750E+03	0.	-2.141E+03	3.359E+03	0.	2.750E+03
-16.00	2.800E+03	0.	-2.191E+03	3.409E+03	0.	2.800E+03
-17.00	2.850E+03	0.	-2.241E+03	3.459E+03	0.	2.850E+03
-18.00	2.900E+03	0.	-2.291E+03	3.509E+03	0.	2.900E+03
-19.00	2.950E+03	0.	-2.341E+03	3.559E+03	0.	2.950E+03
-20.00	3.000E+03	0.	-2.391E+03	3.609E+03	0.	3.000E+03
-21.00	3.050E+03	0.	-2.441E+03	3.659E+03	0.	3.050E+03
-22.00	3.100E+03	0.	-2.491E+03	3.709E+03	0.	3.100E+03
-23.00	3.150E+03	0.	-2.541E+03	3.759E+03	0.	3.150E+03
-24.00	3.200E+03	0.	-2.591E+03	3.809E+03	0.	3.200E+03
-25.00	3.250E+03	0.	-2.641E+03	3.859E+03	0.	3.250E+03
-26.00	3.300E+03	0.	-2.691E+03	3.909E+03	0.	3.300E+03
-27.00	3.350E+03	0.	-2.741E+03	3.959E+03	0.	3.350E+03
-28.00	3.400E+03	0.	-2.791E+03	4.009E+03	0.	3.400E+03
-29.00	3.450E+03	0.	-2.841E+03	4.059E+03	0.	3.450E+03
-30.00	3.500E+03	0.	-2.891E+03	4.109E+03	0.	3.500E+03
-31.00	3.550E+03	0.	-2.941E+03	4.159E+03	0.	3.550E+03

Figure 29. (Concluded)

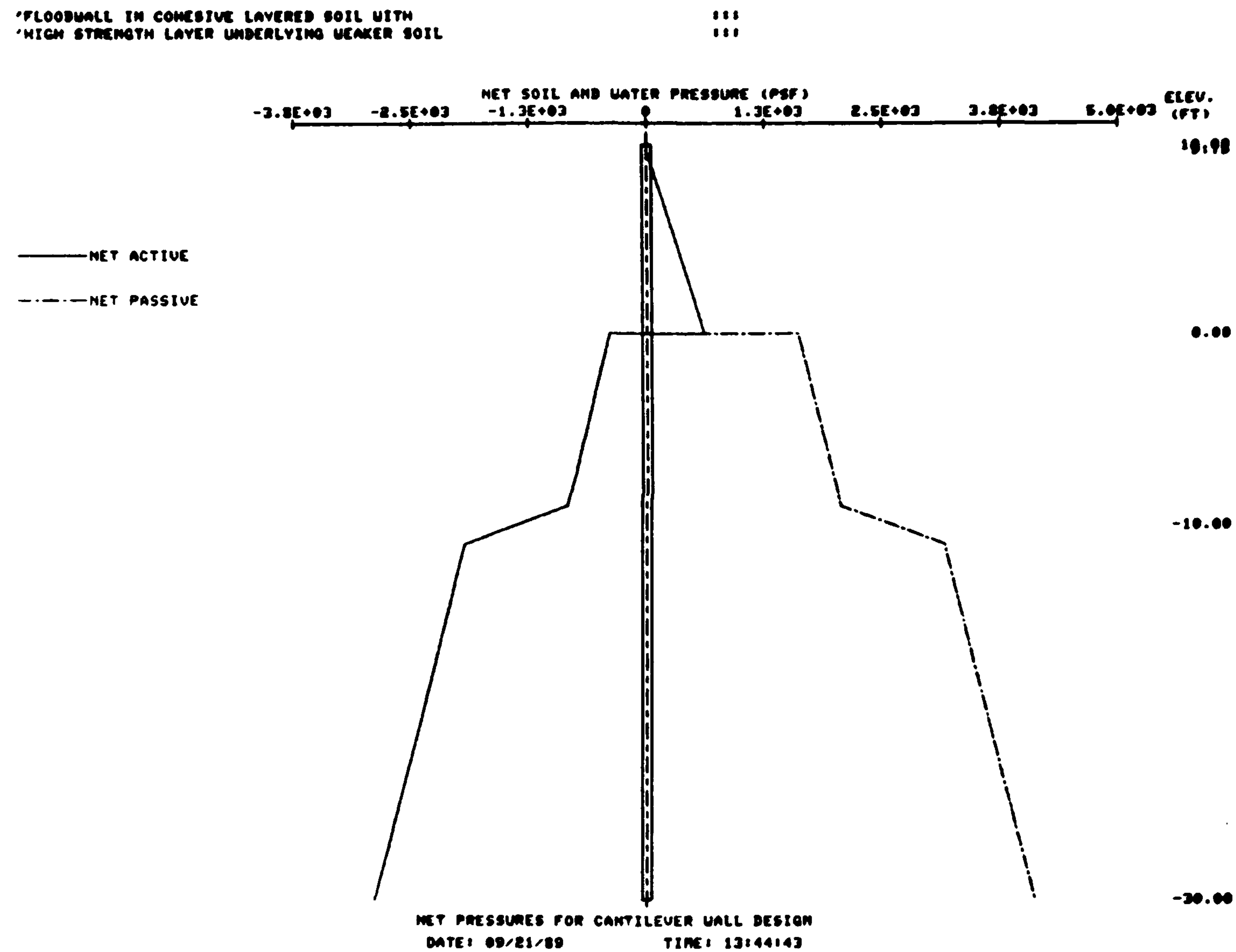


Figure 30. Initial net pressures for Example CANT2

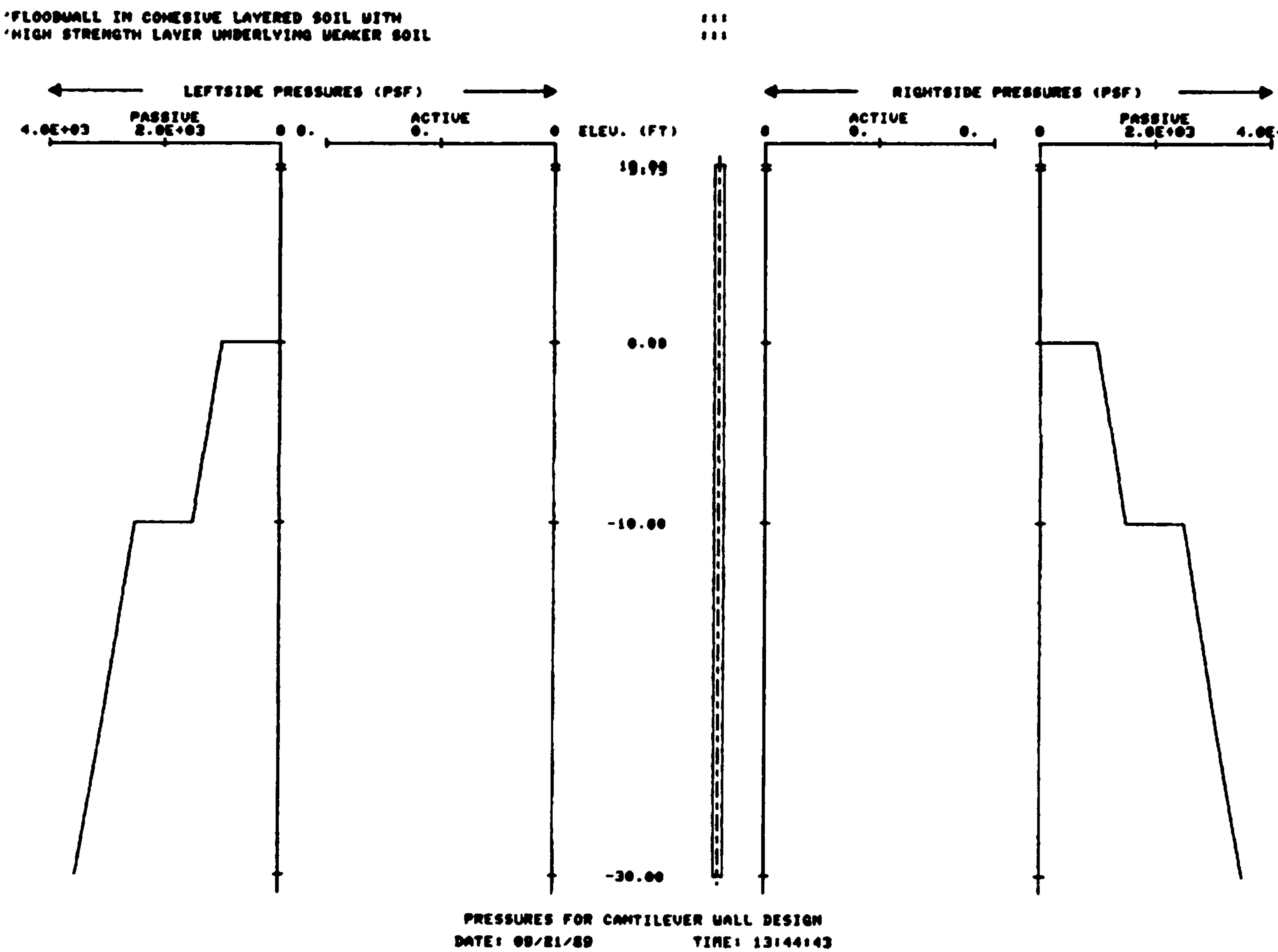


Figure 31. Initial active and passive pressures for Example CANT2

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 08/22/89                                                  TIME: 14:51:17

                   ****************************
                   *  SUMMARY OF RESULTS FOR  *
                   *  CANTILEVER WALL DESIGN  *
                   ****************************

I.--HEADING

  'FLOODWALL IN COHESIVE LAYERED SOIL WITH

  'HIGH STRENGTH LAYER UNDERLYING WEAKER SOIL


II.--SUMMARY

    RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
    AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

     LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
    AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

WALL BOTTOM ELEV. (FT)    :       -13.58
     PENETRATION (FT)     :        13.58

MAX. BEND. MOMENT (LB-FT) :       18648.
     AT ELEVATION (FT)    :        -6.00

MAX. SCALED DEFL. (LB-IN3):   5.0887E+09
     AT ELEVATION (FT)    :        10.00

    (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
    ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
    IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)
```

Figure 32. Summary of results for Example CANT2

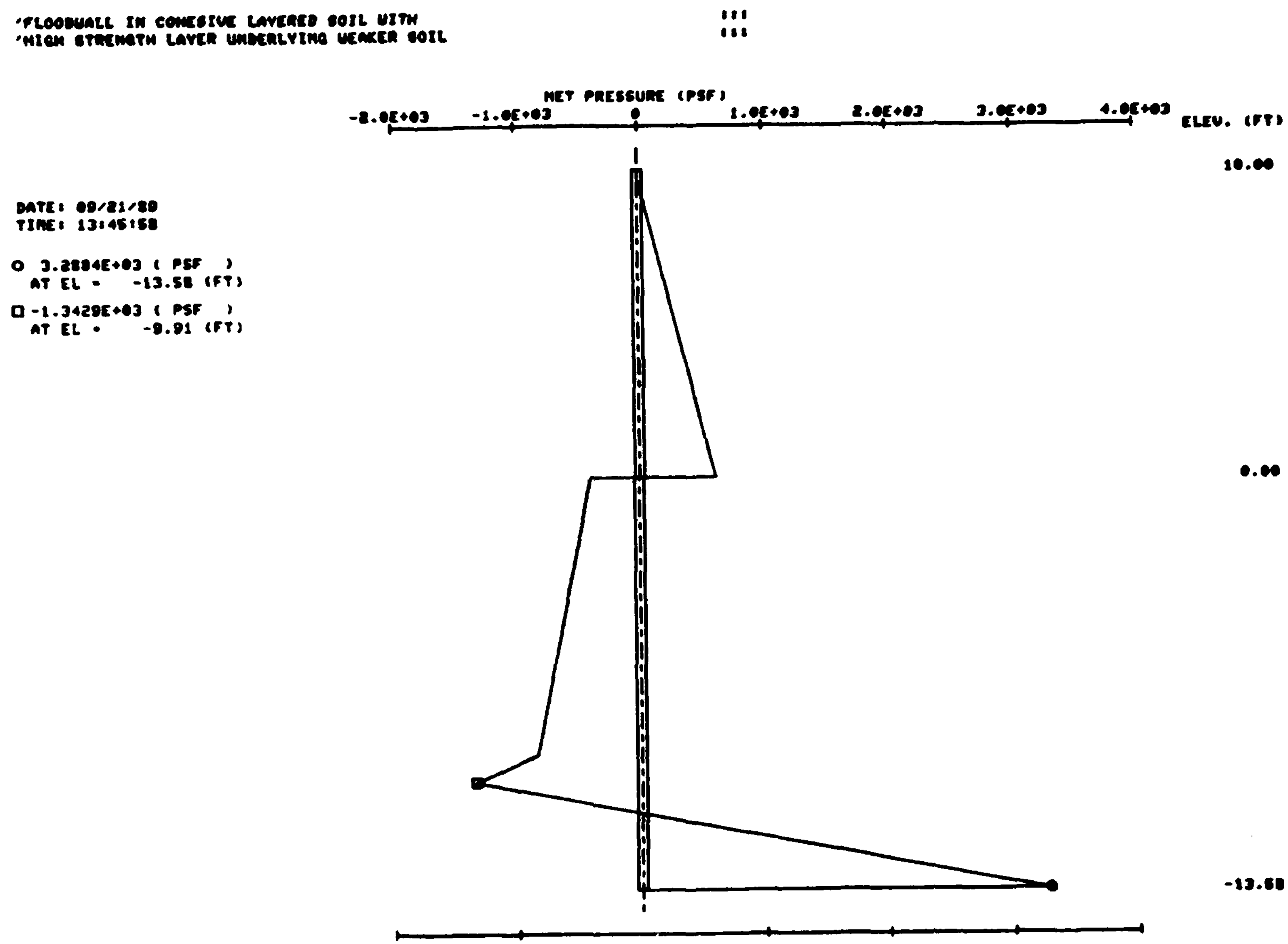


Figure 33. Final design net pressures for Example CANT2

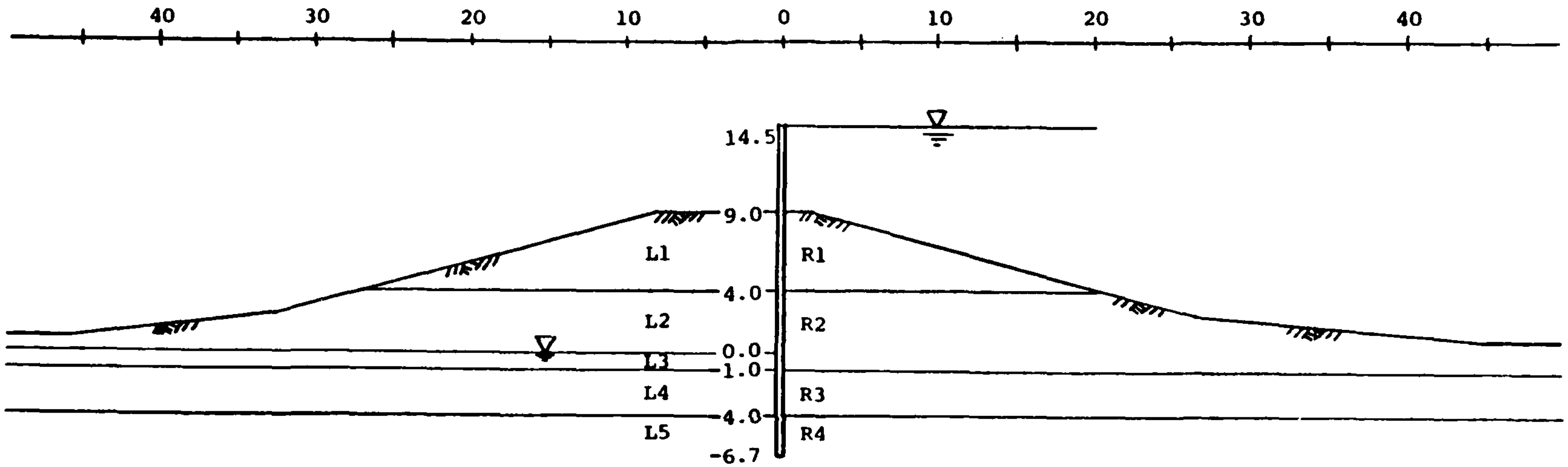
Example CANT3

82. The floodwall/levee system shown in Figure 34 requires a wedge method for evaluation of the soil pressures. The input file for this system is given in Figure 35, and execution of the program is shown in Figure 36. The plot of input geometry presented in Figure 37 is distorted since the plot limits specified (see Figure 36) do not define a square.

83. The sweep search wedge method was selected (see Figure 36) for evaluation of the design pressures. The resulting pressures are shown in Figures 38, 39, and 40. The weak layer between el -1 and -4 ft on the left side results in low passive pressures on the left side of the wall. When the leftside passive, rightside active, and net water pressures are combined, the total net pressure in the vicinity of the weak layer has a spurious reversal of direction near the weak layer. Execution was terminated at this point, the program was restarted, and the fixed wedge method was selected for solution.

84. The soil pressures produced by the fixed wedge method are shown in Figures 41, 42, and 43. It should be emphasized that the fixed wedge tends to overestimate passive pressures for this situation. It is the responsibility of the user to judge the validity of the results.

85. The summary of results and complete output for this example are tabulated in Figures 44 and 45.



a. Wall and soil profile

Layer	γ (PSF)	ϕ (DEG)
R1	102.5	23
R2	122.5	30
R3	102.5	23
R4	122.5	30
L1	107.5	23
L2	122.0	30
L3	122.5	30
L4	102.5	23
L5	122.5	30

b. Soil properties

Figure 34. System for Example CANT3

```
1000 'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
1010 'IRREGULAR GROUND SURFACE
1020 'INTERSPERSED STRONG AND WEAK SOIL LAYERS
1030 CONTROL  C  D    1.50    1.50
1040 WALL       14.50
1050 SURFACE RIGHTSIDE   4
1060      0.00      9.00      2.00      9.00     26.50      2.50
1070     45.00      1.00
1080 SURFACE  LEFTSIDE   4
1090      0.00      9.00      8.00      9.00     32.50      2.50
1100     46.00      1.00
1110 SOIL RIGHTSIDE  STRENGTH    4   0.00    0.00
1120 102.50 102.50  23.00  0.00  0.00  0.00  4.00  0.00  0.00  0.00
1130 122.50 122.50  30.00  0.00  0.00  0.00 -1.00  0.00  0.00  0.00
1140 102.50 102.50  23.00  0.00  0.00  0.00 -4.00  0.00  0.00  0.00
1150 122.50 122.50  30.00  0.00  0.00  0.00  0.00  0.00
1160 SOIL  LEFTSIDE  STRENGTH    5   0.00    0.00
1170 107.50 107.50  23.00  0.00  0.00  0.00  4.00  0.00  0.00  0.00
1180 122.00 122.00  30.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00
1190 122.50 122.50  30.00  0.00  0.00  0.00 -1.00  0.00  0.00  0.00
1200 102.50 102.50  23.00  0.00  0.00  0.00 -4.00  0.00  0.00  0.00
1210 122.50 122.50  30.00  0.00  0.00  0.00  0.00  0.00
1220 WATER ELEVATIONS    62.50   14.50    0.00
1230 FINISH
```

Figure 35. Input file for Example CANT3

```
     PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                                BY CLASSICAL METHODS
     DATE: 08/24/89                                                TIME: 1:17:47

     ARE INPUT DATA TO BE READ FROM YOUR TERMINAL OR A FILE?
     ENTER 'TERMINAL' OR 'FILE'.
 ? F
     ENTER INPUT FILE NAME (6 CHARACTERS MAXIMUM).
       ?cant3i
     INPUT COMPLETE.
     DO YOU WANT INPUT DATA ECHOPRINTED TO YOUR TERMINAL,
     TO A FILE, TO BOTH, OR NEITHER?
     ENTER 'TERMINAL', 'FILE', 'BOTH', OR 'NEITHER'.
 ? n
     INPUT COMPLETE.
     DO YOU WANT TO EDIT INPUT DATA?
     ENTER 'YES' OR 'NO'.
 ? n
     DO YOU WANT TO PLOT INPUT DATA?
     ENTER 'YES' OR 'NO'.
 ? y
     MAXIMA AND MINIMA DEFINED BY INPUT DATA

     <-ELEVATION (FT)->        <DIST. FROM WALL (FT)>
     MAXIMUM    MINIMUM        LEFTSIDE     RIGHTSIDE
       14.50      -4.00          46.00         45.00

     ENTER DESIRED PLOT LIMITS

     <------ELEVATION (FT)------>    <DIST. FROM WALL (FT)>
     TOP OF PLOT   BOTTOM OF PLOT    LEFTSIDE     RIGHTSIDE
 ? 15 -5 50 50

        --------------------------------------
        -(NOTE: GEOMETRY PLOT PRODUCED HERE.)-
        --------------------------------------

     DO YOU WANT TO REPLOT INPUT GEOMETRY WITH DIFFERENT LIMITS?
     ENTER 'YES' OR 'NO'.
 ? n
     DO YOU WANT TO CONTINUE WITH THE SOLUTION?
     ENTER 'YES' OR 'NO'.
 ? y
     DO YOU WANT SOIL PRESSURES CALCULATED BY THE SWEEP SEARCH WEDGE METHOD
     OR BY THE FIXED SURFACE WEDGE METHOD?
     ENTER 'SWEEP' OR 'FIXED'.
 ? s
     DO YOU WANT A LISTING OF SOIL PRESSURES
     BEFORE CONTINUING WITH THE DESIGN?
     ENTER 'YES' OR 'NO'.
 ? y
```

Figure 36. Program execution for Example CANT3 (Continued)

```
    DO YOU WANT SOIL PRESSURES PRINTED TO YOUR TERMINAL, TO A FILE, OR BOTH?
    ENTER 'TERMINAL', 'FILE', OR 'BOTH'.
? f
    ENTER OUTPUT FILE NAME (6 CHARACTERS MAXIMUM).
? cant3o
    DO YOU WANT TO PLOT SOIL PRESSURES?
    ENTER 'YES' OR 'NO'.
? y

        ---------------------------------------
        -(NOTE: PRESSURE PLOTS PRODUCED HERE.)-
        ---------------------------------------


    DO YOU WANT TO CONTINUE WITH THE SOLUTION?
    ENTER 'YES' OR 'NO'.
? n
    DO YOU WANT TO EDIT INPUT DATA?
    ENTER 'YES' OR 'NO'.
? n


    LAST INPUT FILE PROCESSED = 'CANT3I'.


    OUTPUT SAVED IN FILE 'CANT3O'.


    DO YOU WANT TO MAKE ANOTHER RUN?
    ENTER 'YES' OR 'NO'.
? n


    ********** NORMAL TERMINATION **********
```

Figure 36. (Concluded)

<------RIGHTSIDE SOIL-------->						
	(WEIGHT)					
LYR	SAT	MST	PHI	C	DEL	ADH
1	102	102	23	0	0	0
2	122	122	30	0	0	0
3	102	102	23	0	0	0
4	122	122	30	0	0	0

<------- LEFTSIDE SOIL-------->						
	(WEIGHT)					
LYR	SAT	MST	PHI	C	DEL	ADH
1	107	107	23	0	0	0
2	122	122	30	0	0	0
3	122	122	30	0	0	0
4	192	102	23	0	0	0
5	122	122	30	0	0	0

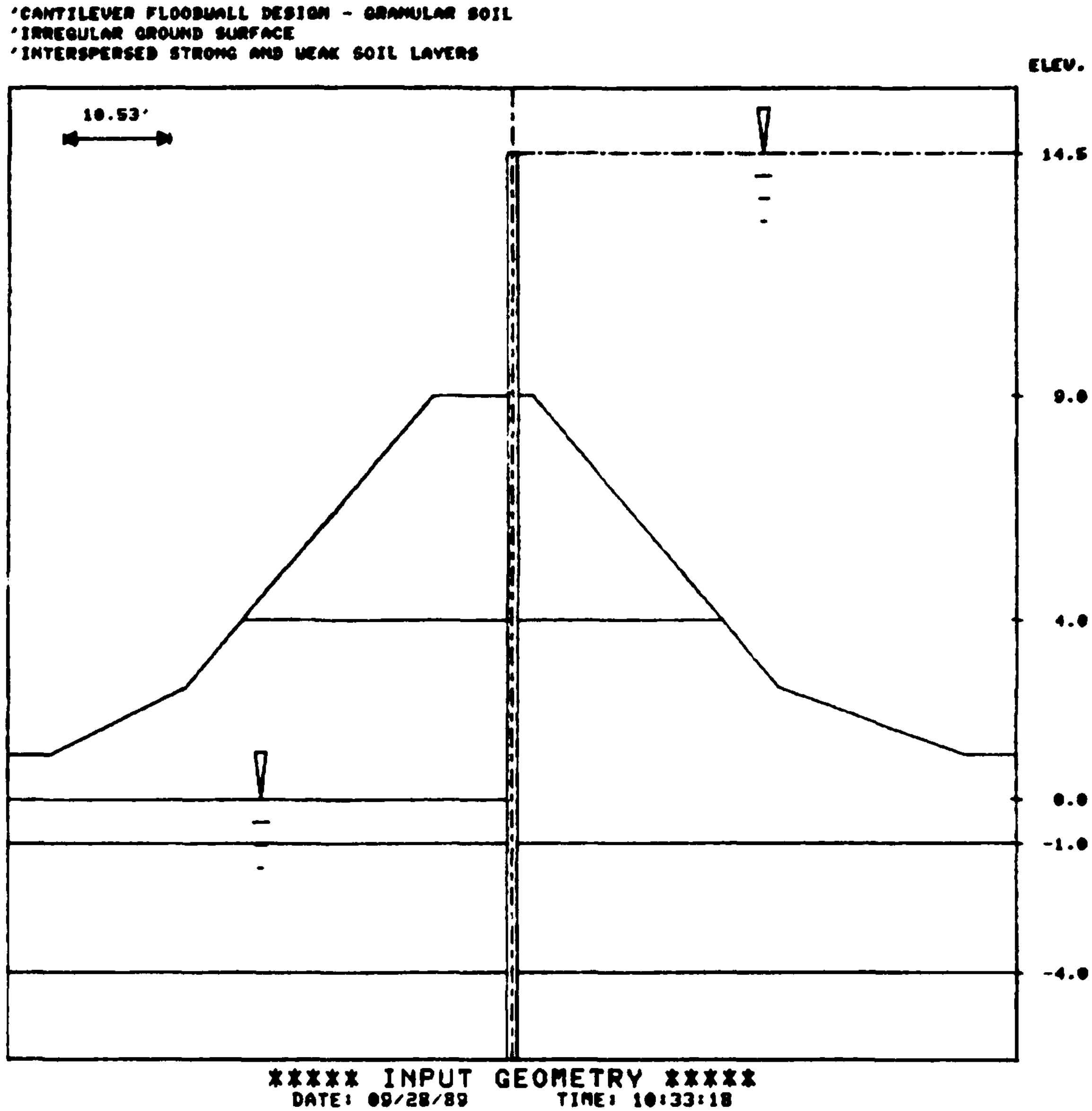


Figure 37. Program plot in input geometry for Example CANT3

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/24/89 TIME: 10:21:09

```
****************************
*    SOIL PRESSURES FOR    *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
'IRREGULAR GROUND SURFACE
'INTERSPERSED STRONG AND WEAK SOIL LAYERS
II.--SOIL PRESSURES
RIGHTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.
LEFTSIDE SOIL PRESSURES DETERMINED BY SWEEP SEARCH WEDGE METHOD.

	<-LEFTSIDE PRESSURES->		<---NET PRESSURES----> (SOIL PLUS WATER)		<RIGHTSIDE PRESSURES->	
ELEV. (FT)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
14.50	0.	0.	0.	0.	0.	0.
13.50	0.	0.	6.250E+01	6.250E+01	0.	0.
12.50	0.	0.	1.250E+02	1.250E+02	0.	0.
11.50	0.	0.	1.875E+02	1.875E+02	0.	0.
10.50	0.	0.	2.500E+02	2.500E+02	0.	0.
9.50	0.	0.	3.125E+02	3.125E+02	0.	0.
9.00	0.	0.	3.438E+02	3.438E+02	0.	0.
8.50	9.397E+01	3.074E+01	2.925E+02	3.792E+02	1.144E+01	3.497E+01
8.00	1.879E+02	6.149E+01	2.412E+02	4.147E+02	2.288E+01	6.993E+01
7.50	2.819E+02	9.223E+01	1.899E+02	4.405E+02	3.432E+01	9.526E+01
6.50	4.699E+02	1.537E+02	8.684E+01	4.772E+02	5.672E+01	1.309E+02
5.67	6.261E+02	2.048E+02	0.	5.123E+02	7.415E+01	1.652E+02
5.50	6.578E+02	2.152E+02	-1.763E+01	5.195E+02	7.769E+01	1.722E+02
4.50	8.458E+02	2.767E+02	-1.232E+02	5.633E+02	9.752E+01	2.149E+02
4.00	1.051E+03	2.795E+02	-2.962E+02	7.017E+02	9.830E+01	3.249E+02
3.50	1.257E+03	2.813E+02	-4.684E+02	8.390E+02	1.006E+02	4.328E+02
2.50	1.429E+03	3.392E+02	-5.533E+02	9.069E+02	1.260E+02	4.962E+02
1.50	1.604E+03	3.971E+02	-6.406E+02	1.006E+03	1.511E+02	5.902E+02
.50	1.795E+03	4.546E+02	-7.440E+02	1.107E+03	1.762E+02	6.869E+02
0.00	1.866E+03	4.797E+02	-7.711E+02	1.162E+03	1.890E+02	7.358E+02
-.50	1.899E+03	4.975E+02	-7.907E+02	1.194E+03	2.018E+02	7.849E+02
-1.00	1.681E+03	5.651E+02	-5.369E+02	1.067E+03	2.378E+02	7.258E+02
-1.50	1.148E+03	6.313E+02	3.120E+01	9.252E+02	2.725E+02	6.502E+02
-2.50	1.146E+03	6.514E+02	5.330E+01	9.002E+02	2.925E+02	6.453E+02
-3.50	1.186E+03	6.667E+02	3.337E+01	8.936E+02	3.126E+02	6.540E+02
-4.00	1.701E+03	6.139E+02	-5.008E+02	1.167E+03	2.937E+02	8.751E+02
-4.50	2.325E+03	5.655E+02	-1.143E+03	1.437E+03	2.760E+02	1.096E+03
-5.50	2.079E+03	5.905E+02	-8.712E+02	1.482E+03	3.011E+02	1.167E+03
-6.50	2.011E+03	6.098E+02	-7.789E+02	1.550E+03	3.261E+02	1.254E+03
-7.50	2.017E+03	6.306E+02	-7.592E+02	1.623E+03	3.513E+02	1.347E+03
-8.50	2.057E+03	6.540E+02	-7.739E+02	1.697E+03	3.768E+02	1.445E+03

Figure 38. Initial soil pressures for Example CANT3
by sweep search wedge method

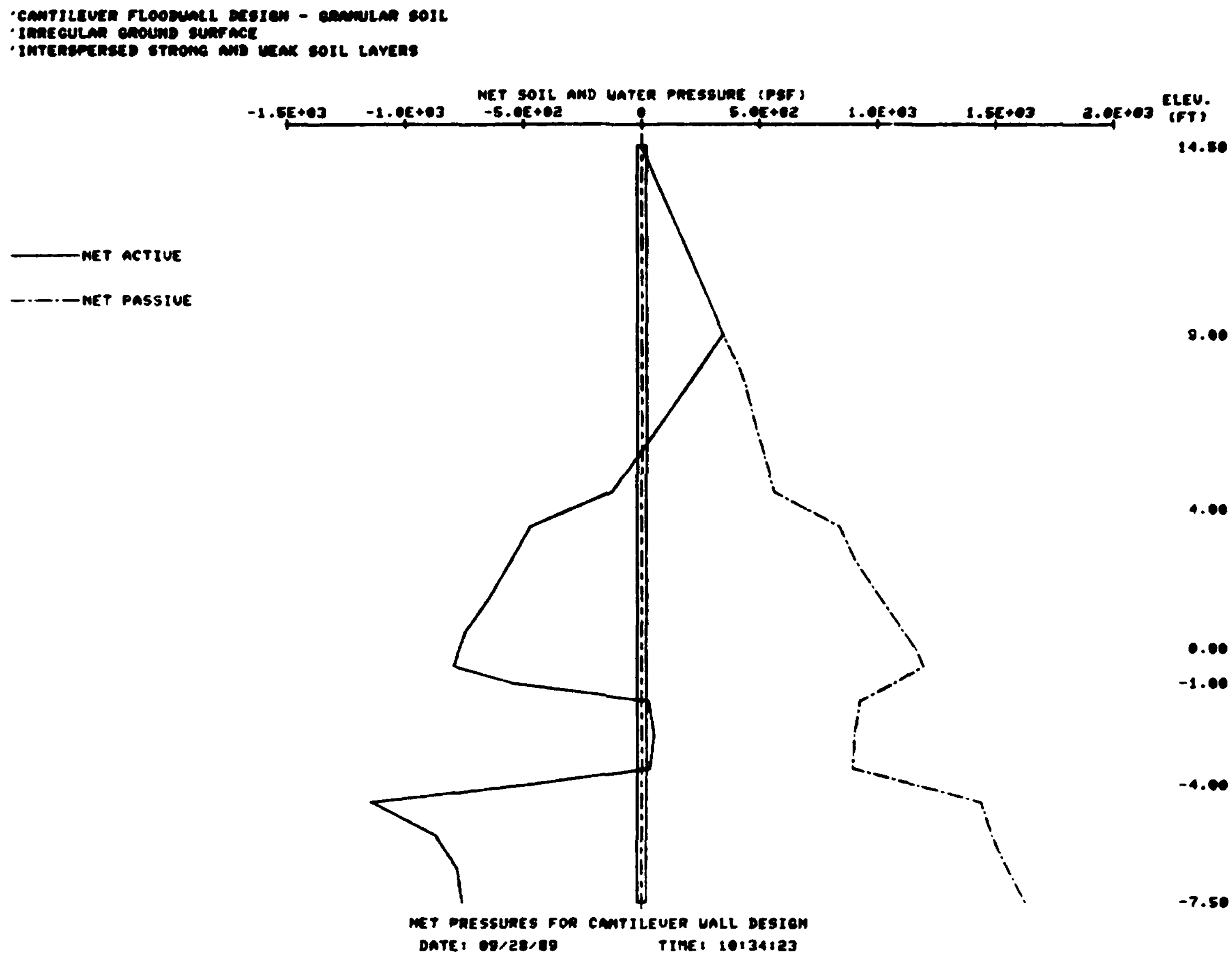


Figure 39. Net pressures by sweep search method for Example CANT3

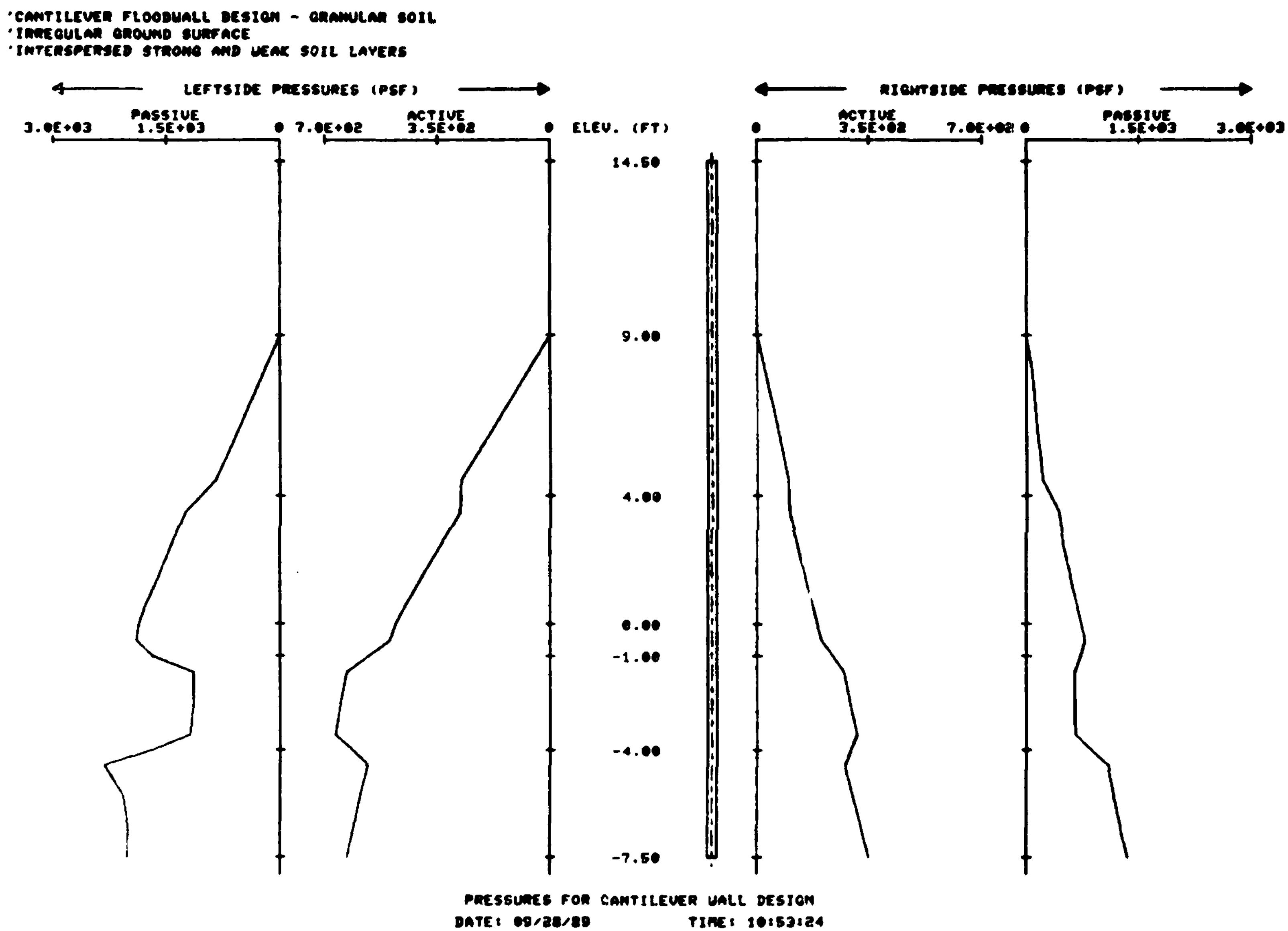


Figure 40. Active and passive soil pressures by sweep search method for Example CANT3

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/24/89 TIME: 10:51:49

```
****************************
*    SOIL PRESSURES FOR    *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING
'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
'IRREGULAR GROUND SURFACE
'INTERSPERSED STRONG AND WEAK SOIL LAYERS

II.--SOIL PRESSURES
RIGHTSIDE SOIL PRESSURES DETERMINED BY FIXED SURFACE WEDGE METHOD.
LEFTSIDE SOIL PRESSURES DETERMINED BY FIXED SURFACE WEDGE METHOD.

	<-LEFTSIDE PRESSURES->		<---NET PRESSURES----> (SOIL PLUS WATER)		<RIGHTSIDE PRESSURES->	
ELEV. (FT)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
14.50	0.	0.	0.	0.	0.	0.
13.50	0.	0.	6.250E+01	6.250E+01	0.	0.
12.50	0.	0.	1.250E+02	1.250E+02	0.	0.
11.50	0.	0.	1.875E+02	1.875E+02	0.	0.
10.50	0.	0.	2.500E+02	2.500E+02	0.	0.
9.50	0.	0.	3.125E+02	3.125E+02	0.	0.
9.00	0.	0.	3.438E+02	3.438E+02	0.	0.
8.50	9.397E+01	3.074E+01	2.925E+02	3.793E+02	1.144E+01	3.504E+01
8.00	1.879E+02	6.149E+01	2.412E+02	4.147E+02	2.289E+01	6.990E+01
7.50	2.819E+02	9.223E+01	1.899E+02	4.471E+02	3.436E+01	1.018E+02
6.50	4.699E+02	1.537E+02	8.660E+01	5.032E+02	5.647E+01	1.569E+02
5.65	6.267E+02	2.063E+02	0.	5.465E+02	7.382E+01	2.000E+02
5.50	6.552E+02	2.159E+02	-1.573E+01	5.544E+02	7.697E+01	2.078E+02
4.50	8.777E+02	2.681E+02	-1.599E+02	6.283E+02	9.284E+01	2.714E+02
4.00	1.050E+03	2.799E+02	-2.976E+02	7.038E+02	9.655E+01	3.274E+02
3.50	1.236E+03	2.907E+02	-4.465E+02	7.933E+02	1.018E+02	3.965E+02
2.50	1.495E+03	3.390E+02	-6.212E+02	9.231E+02	1.236E+02	5.121E+02
1.50	1.696E+03	3.972E+02	-7.349E+02	1.029E+03	1.490E+02	6.142E+02
.50	1.895E+03	4.546E+02	-8.453E+02	1.137E+03	1.743E+02	7.164E+02
0.00	1.984E+03	4.780E+02	-8.913E+02	1.198E+03	1.863E+02	7.702E+02
-.50	1.992E+03	5.082E+02	-8.812E+02	1.200E+03	2.044E+02	8.022E+02
-1.00	1.869E+03	5.648E+02	-7.278E+02	1.121E+03	2.352E+02	7.800E+02
-1.50	1.749E+03	6.152E+02	-5.796E+02	1.042E+03	2.628E+02	7.513E+02
-2.50	1.696E+03	6.525E+02	-4.984E+02	1.024E+03	2.910E+02	7.707E+02
-3.50	1.785E+03	6.443E+02	-5.792E+02	1.122E+03	2.997E+02	8.596E+02
-4.00	1.939E+03	6.106E+02	-7.424E+02	1.259E+03	2.900E+02	9.633E+02
-4.50	2.103E+03	5.789E+02	-9.152E+02	1.407E+03	2.816E+02	1.080E+03
-5.50	2.233E+03	5.782E+02	-1.030E+03	1.547E+03	2.966E+02	1.219E+03
-6.50	2.289E+03	5.996E+02	-1.060E+03	1.626E+03	3.226E+02	1.320E+03
-7.50	2.354E+03	6.197E+02	-1.100E+03	1.709E+03	3.479E+02	1.422E+03
-8.50	2.422E+03	6.403E+02	-1.142E+03	1.790E+03	3.733E+02	1.524E+03

Figure 41. Initial pressures for Example CANT3
by fixed surface wedge method

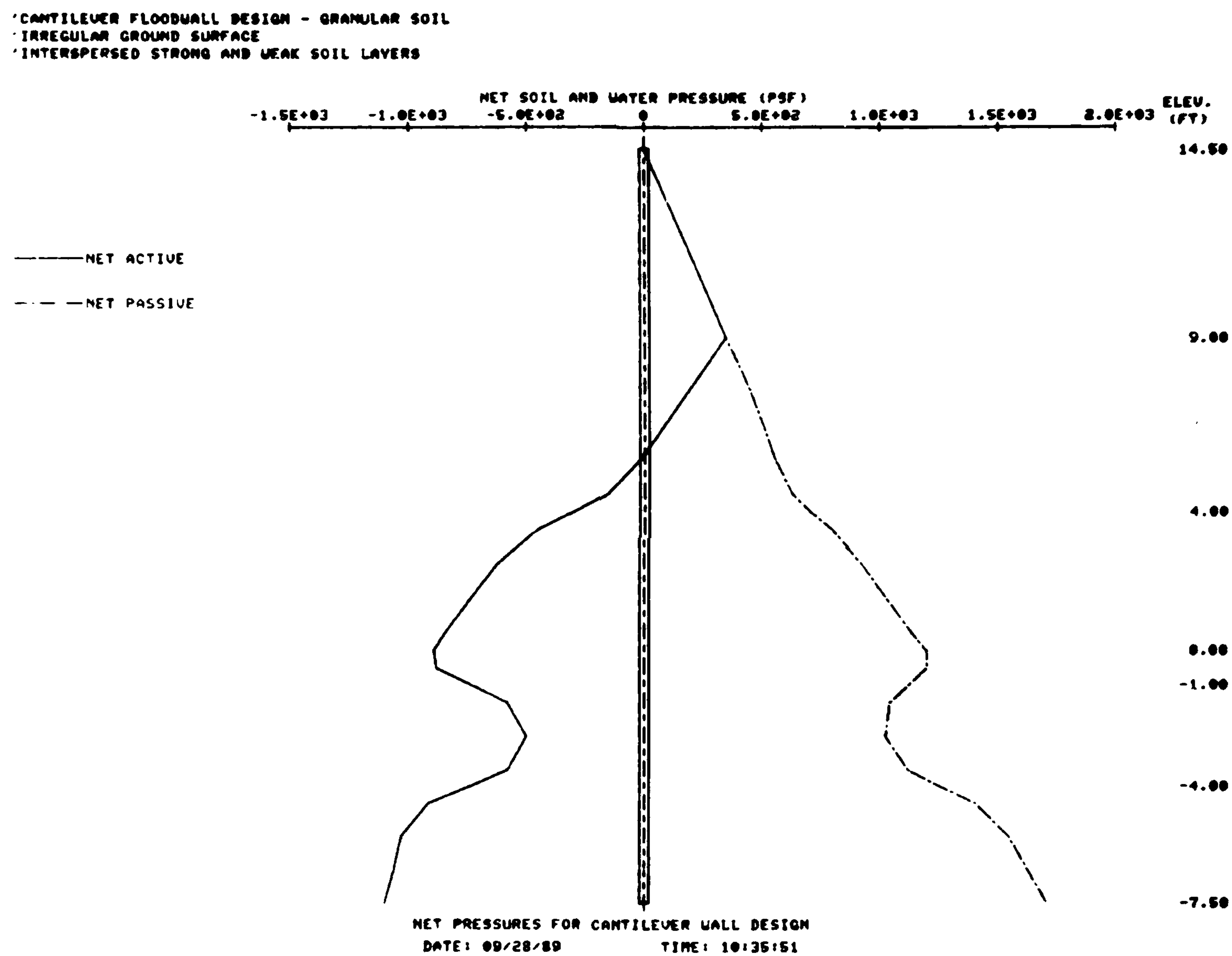


Figure 42. Net pressures by fixed surface wedge method for Example CANT3

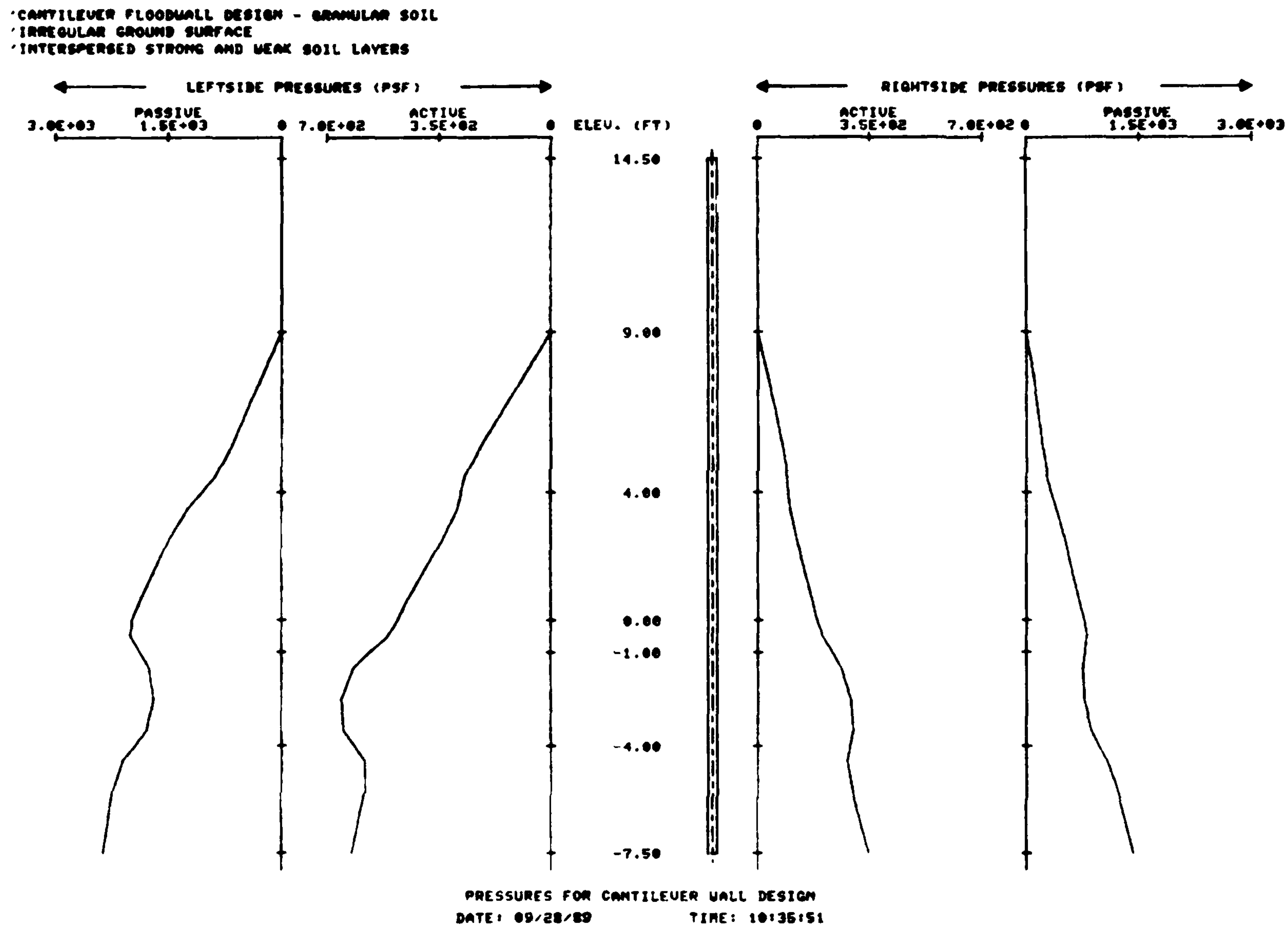


Figure 43. Active and passive soil pressures by fixed surface wedge method for Example CANT3

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                             BY CLASSICAL METHODS
DATE: 08/24/89                                                 TIME: 10:53:16

                       ****************************
                       *  SUMMARY OF RESULTS FOR  *
                       *  CANTILEVER WALL DESIGN  *
                       ****************************

I.--HEADING

  'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
  'IRREGULAR GROUND SURFACE
  'INTERSPERSED STRONG AND WEAK SOIL LAYERS

II.--SUMMARY


     RIGHTSIDE SOIL PRESSURES DETERMINED BY FIXED SURFACE WEDGE METHOD.

      LEFTSIDE SOIL PRESSURES DETERMINED BY FIXED SURFACE WEDGE METHOD.

WALL BOTTOM ELEV. (FT)    :         -5.29
      PENETRATION (FT)    :         14.29

MAX. BEND. MOMENT (LB-FT) :        10352.
      AT ELEVATION (FT)   :          1.50

MAX. SCALED DEFL. (LB-IN3):    1.8430E+09
      AT ELEVATION (FT)   :         14.50

     (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
     ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
     IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)
```

Figure 44. Summary of results for Example CANT3

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/24/89 TIME: 10:53:16

```
****************************
*   COMPLETE RESULTS FOR   *
*  CANTILEVER WALL DESIGN  *
****************************
```

I.--HEADING

'CANTILEVER FLOODWALL DESIGN - GRANULAR SOIL
'IRREGULAR GROUND SURFACE
'INTERSPERSED STRONG AND WEAK SOIL LAYERS

III.--RESULTS

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
14.50	0.	0.	1.8430E+09	0.00
13.50	10.	31.	1.6901E+09	62.50
12.50	83.	125.	1.5373E+09	125.00
11.50	281.	281.	1.3846E+09	187.50
10.50	667.	500.	1.2324E+09	250.00
9.50	1302.	781.	1.0814E+09	312.50
9.00	1733.	945.	1.0067E+09	343.75
8.50	2247.	1104.	9.3270E+08	292.47
8.00	2833.	1238.	8.5970E+08	241.19
7.50	3480.	1346.	7.8792E+08	189.93
6.50	4903.	1484.	6.4919E+08	86.60
5.65	6180.	1520.	5.3831E+08	0.00
5.50	6413.	1519.	5.1895E+08	-15.73
4.50	7901.	1431.	3.9978E+08	-159.87
4.00	8591.	1317.	3.4516E+08	-297.56
3.50	9206.	1131.	2.9424E+08	-446.47
2.50	10085.	597.	2.0455E+08	-621.15
1.50	10352.	-81.	1.3219E+08	-734.91
.50	9886.	-871.	7.7618E+07	-845.28
0.00	9343.	-1305.	5.6798E+07	-891.26
-.31	8902.	-1577.	4.6061E+07	-885.12
-.50	8580.	-1739.	4.0006E+07	-791.58
-1.00	7621.	-2075.	2.6914E+07	-550.47
-1.50	6525.	-2290.	1.7110E+07	-309.36
-2.50	4161.	-2358.	5.4439E+06	172.86
-3.50	1970.	-1944.	9.9318E+05	655.09
-4.00	1090.	-1556.	2.7739E+05	896.20
-4.50	433.	-1048.	4.0337E+04	1137.31
-5.29	0.	0.	0.	1517.94

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 45. Complete results for Example CANT3

Anchored Walls

Example ANCH1

86. The anchored wall shown in Figure 46 was designed for a factor of safety of 1.0 for all effects. The input file for this system is given in Figure 47. Even though the soil surfaces are unsymmetric, the soil layer data may be described as "symmetric" since the layer data are the same (including layer bottom elevation and bottom slope) for each soil layer on each side. Note that the moist unit weight has been used for the soil above el 22 ft for the soil on the right side and the buoyant unit weight has been calculated by the program from the saturated unit weight for the soil below water on each side of the wall. The echoprint of input data is shown in Figure 48.

87. The summary of results and complete output of results for each of the three methods of anchored wall analysis are given in Figures 49 through 52. Plots of results for the free earth method are shown in Figures 53 through 57. Similar plots for the equivalent beam and fixed earth method are also available.

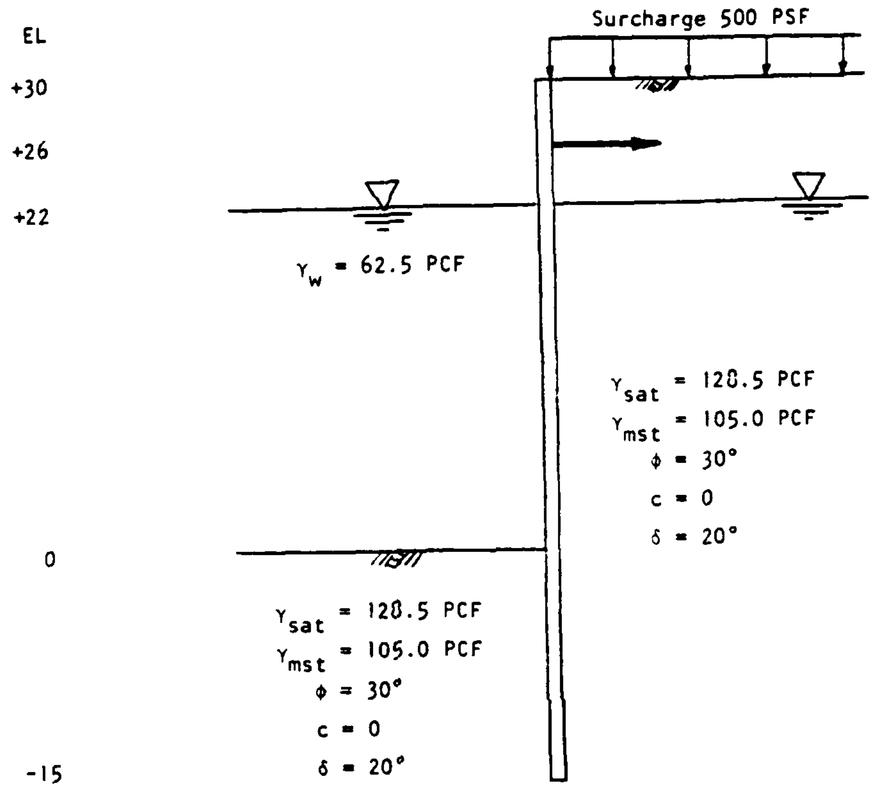


Figure 46. System for Example ANCH1

```
1000 'ANCHORED RETAINING WALL IN GRANULAR SOIL
1010 'DESIGN FOR FS = 1 ON BOTH ACTIVE AND PASSIVE
1020 CONTROL  A  D    1.00    1.00
1030 WALL       30.00      26.00
1040 SURFACE RIGHTSIDE    1
1050       0.00      30.00
1060 SURFACE  LEFTSIDE    1
1070       0.00       0.00
1080 SOIL BOTH  STRENGTH    1    0.00    0.00
1090  128.50  105.00   30.00    0.00   20.00    0.00    0.00    0.00
1100 WATER ELEVATIONS    62.50   22.00   22.00
1110 VERTICAL UNIFORM RIGHTSIDE      500.00
1120 FINISH
```

Figure 47. Input file for Example ANCH1

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 08/24/89                                                TIME: 11:47:35
                            ****************
                            *  INPUT DATA  *
                            ****************
I.--HEADING:
  'ANCHORED RETAINING WALL IN GRANULAR SOIL
  'DESIGN FOR FS = 1 ON BOTH ACTIVE AND PASSIVE

II.--CONTROL
  ANCHORED   WALL DESIGN

  LEVEL 1 FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
  LEVEL 1 FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00

III.--WALL DATA
  ELEVATION AT TOP OF WALL      =    30.00 (FT)
  ELEVATION AT ANCHOR           =    26.00 (FT)

IV.--SURFACE POINT DATA
  IV.A--RIGHTSIDE
     DIST. FROM     ELEVATION
     WALL (FT)         (FT)
           0.00        30.00

  IV.B-- LEFTSIDE
     DIST. FROM     ELEVATION
     WALL (FT)         (FT)
           0.00         0.00

V.--SOIL LAYER DATA
  V.A.--RIGHTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT

                ANGLE OF          ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL   COH-     WALL      ADH-    <--BOTTOM--> <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION   FRICTION   ESION    ELEV.  SLOPE ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)     (DEG)    (PSF)    (FT) (FT/FT)
128.50  105.00    30.00    0.0     20.00      0.0                   DEF  DEF

  V.B.-- LEFTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT

                ANGLE OF          ANGLE OF                         <-SAFETY->
  SAT.   MOIST  INTERNAL   COH-     WALL      ADH-    <--BOTTOM--> <-FACTOR->
 WGHT.   WGHT.  FRICTION  ESION   FRICTION   ESION    ELEV.  SLOPE ACT. PASS.
 (PCF)   (PCF)    (DEG)   (PSF)     (DEG)    (PSF)    (FT) (FT/FT)
128.50  105.00    30.00    0.0     20.00      0.0                   DEF  DEF
```

Figure 48. Echoprint of input data for Example ANCH1 (Continued)

```
VI.--WATER DATA

     UNIT WEIGHT          =     62.50 (PCF)
     RIGHTSIDE ELEVATION =     22.00 (FT)
      LEFTSIDE ELEVATION =     22.00 (FT)
     NO SEEPAGE


VII.--SURFACE LOADS

  VII.A.--RIGHTSIDE SURFACE LOADS

    VII.A.1.--SURFACE LINE LOADS
     NONE

    VII.A.2.--SURFACE DISTRIBUTED LOADS
     UNIFORM LOAD =      500.00 (PSF)

  VII.B.-- LEFTSIDE SURFACE LOADS
     NONE


VIII.--HORIZONTAL LOADS
     NONE
```

Figure 48. (Concluded)

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/24/89 TIME: 11:48:29

```
****************************
*  SUMMARY OF RESULTS FOR  *
*   ANCHORED WALL DESIGN   *
****************************
```

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS = 1 ON BOTH ACTIVE AND PASSIVE

II.--SUMMARY

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

METHOD	:	FREE EARTH	EQUIV. BEAM	FIXED EARTH
WALL BOTTOM ELEV. (FT)	:	-8.46	-13.85	-14.40
PENETRATION (FT)	:	8.46	13.85	14.40
MAX. BEND. MOMENT (LB-FT)	:	-71921.	-54816.	-51212.
AT ELEVATION (FT)	:	9.00	11.00	11.00
MAX. SCALED DEFL. (LB-IN3)	:	1.4639E+10	-7.9612E+09	9.3456E+09
AT ELEVATION (FT)	:	9.00	-13.85	10.00
ANCHOR FORCE (LB)	:	8471.	7410.	7170.

(NOTE: PENETRATION FOR EQUIVALENT BEAM
METHOD DOES NOT INCLUDE INCREASE
PRESCRIBED BY DRAFT EM 1110-2-2906.)

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 49. Summary of results for Example ANCH1

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/24/89 TIME: 11:48:29

```
****************************
*   COMPLETE RESULTS FOR   *
*   ANCHORED WALL DESIGN   *
*   BY FREE EARTH METHOD   *
****************************
```

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS = 1 ON BOTH ACTIVE AND PASSIVE

II.--RESULTS (ANCHOR FORCE = 8471. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	0.	0.	-5.4160E+09	139.69
29.00	75.	154.	-4.0628E+09	169.03
28.00	318.	338.	-2.7093E+09	198.36
27.00	761.	551.	-1.3553E+09	227.70
26.00	1430.	793.	0.	257.03
26.00	1430.	-7678.	0.	257.03
25.00	-6114.	-7406.	1.3554E+09	286.37
24.00	-13372.	-7105.	2.7003E+09	315.70
23.00	-20315.	-6775.	4.0221E+09	345.04
22.00	-26912.	-6415.	5.3089E+09	374.37
21.00	-33137.	-6031.	6.5492E+09	392.81
20.00	-38969.	-5629.	7.7323E+09	411.25
19.00	-44389.	-5209.	8.8482E+09	429.69
18.00	-49381.	-4770.	9.8874E+09	448.13
17.00	-53923.	-4313.	1.0841E+10	466.57
16.00	-58000.	-3837.	1.1702E+10	485.01
15.00	-61591.	-3343.	1.2463E+10	503.45
14.00	-64679.	-2830.	1.3117E+10	521.89
13.00	-67245.	-2299.	1.3660E+10	540.33
12.00	-69271.	-1749.	1.4086E+10	558.77
11.00	-70738.	-1181.	1.4393E+10	577.21
10.00	-71627.	-595.	1.4578E+10	595.65
9.00	-71921.	10.	1.4639E+10	614.09
8.00	-71601.	633.	1.4576E+10	632.52
7.00	-70649.	1275.	1.4389E+10	650.96
6.00	-69045.	1935.	1.4080E+10	669.40
5.00	-66772.	2614.	1.3652E+10	687.84
4.00	-63812.	3311.	1.3109E+10	706.28
3.00	-60145.	4026.	1.2455E+10	724.72
2.00	-55753.	4760.	1.1698E+10	743.16
1.00	-50618.	5513.	1.0845E+10	761.60

Figure 50. Complete results for free earth method for Example ANCH1 (Continued)

0.00	-44721.	6283.	9.9038E+09	780.04
-1.00	-38108.	6883.	8.8858E+09	419.83
-2.00	-31075.	7123.	7.8020E+09	59.61
-2.17	-29895.	7128.	7.6171E+09	0.00
-3.00	-23982.	7003.	6.6645E+09	-300.60
-4.00	-17189.	6522.	5.4855E+09	-660.81
-5.00	-11058.	5681.	4.2767E+09	-1021.03
-6.00	-5947.	4480.	3.0487E+09	-1381.24
-7.00	-2218.	2919.	1.8102E+09	-1741.45
-8.00	-230.	997.	5.6757E+08	-2101.67
-8.46	-0.	0.	0.	-2266.11

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 50. (Concluded)

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 08/24/89                                               TIME: 11:48:29

                      ****************************
                      *   COMPLETE RESULTS FOR   *
                      *   ANCHORED WALL DESIGN   *
                      *   BY EQUIV. BEAM METHOD  *
                      ****************************

I.--HEADING

  'ANCHORED RETAINING WALL IN GRANULAR SOIL
  'DESIGN FOR FS = 1 ON BOTH ACTIVE AND PASSIVE

II.--RESULTS  (ANCHOR FORCE =         7410. (LB))
```

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	0.	0.	-3.3642E+09	139.69
29.00	75.	154.	-2.5239E+09	169.03
28.00	318.	338.	-1.6834E+09	198.36
27.00	761.	551.	-8.4240E+08	227.70
26.00	1430.	793.	0.	257.03
26.00	1430.	-6616.	0.	257.03
25.00	-5053.	-6345.	8.4277E+08	286.37
24.00	-11249.	-6044.	1.6769E+09	315.70
23.00	-17130.	-5713.	2.4915E+09	345.04
22.00	-22666.	-5354.	3.2767E+09	374.37
21.00	-27830.	-4970.	4.0227E+09	392.81
20.00	-32600.	-4568.	4.7207E+09	411.25
19.00	-36959.	-4148.	5.3624E+09	429.69
18.00	-40889.	-3709.	5.9403E+09	448.13
17.00	-44371.	-3251.	6.4477E+09	466.57
16.00	-47386.	-2775.	6.8784E+09	485.01
15.00	-49915.	-2281.	7.2273E+09	503.45
14.00	-51942.	-1769.	7.4900E+09	521.89
13.00	-53446.	-1237.	7.6630E+09	540.33
12.00	-54411.	-688.	7.7438E+09	558.77
11.00	-54816.	-120.	7.7306E+09	577.21
10.00	-54644.	466.	7.6228E+09	595.65
9.00	-53877.	1071.	7.4207E+09	614.09
8.00	-52496.	1695.	7.1255E+09	632.52
7.00	-50482.	2336.	6.7397E+09	650.96
6.00	-47817.	2997.	6.2668E+09	669.40
5.00	-44482.	3675.	5.7113E+09	687.84
4.00	-40460.	4372.	5.0791E+09	706.28
3.00	-35732.	5088.	4.3771E+09	724.72
2.00	-30278.	5822.	3.6134E+09	743.16
1.00	-24082.	6574.	2.7975E+09	761.60

Figure 51. Complete results for equivalent beam method for Example ANCH1 (Continued)

0.00	-17124.	7345.	1.9401E+09	780.04
-1.00	-9449.	7945.	1.0532E+09	419.83
-2.00	-1355.	8185.	1.5007E+08	59.61
-2.17	0.	8189.	0.	0.00
-3.00	6800.	8064.	-7.5541E+08	-300.60
-4.00	14653.	7583.	-1.6492E+09	-660.81
-5.00	21846.	6742.	-2.5177E+09	-1021.03
-6.00	28018.	5541.	-3.3487E+09	-1381.24
-7.00	32809.	3980.	-4.1314E+09	-1741.45
-8.00	35858.	2058.	-4.8577E+09	-2101.67
-9.00	36806.	-223.	-5.5223E+09	-2461.88
-10.00	35291.	-2865.	-6.1237E+09	-2822.09
-11.00	30955.	-5868.	-6.6645E+09	-3182.31
-12.00	23436.	-9230.	-7.1523E+09	-3542.52
-13.00	12375.	-12953.	-7.6000E+09	-3902.73
-13.85	0.	-16379.	-7.9612E+09	-4207.12

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 51. (Concluded)

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/24/89 TIME: 11:43:29

```
****************************
*   COMPLETE RESULTS FOR   *
*   ANCHORED WALL DESIGN   *
*  BY FIXED  EARTH METHOD  *
****************************
```

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'DESIGN FOR FS = 1 ON BOTH ACTIVE AND PASSIVE

II.--RESULTS (ANCHOR FORCE = 7170. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
30.00	0.	0.	-3.7241E+09	139.69
29.00	75.	154.	-2.7938E+09	169.03
28.00	318.	338.	-1.8634E+09	198.36
27.00	761.	551.	-9.3235E+08	227.70
26.00	1430.	793.	0.	257.03
26.00	1430.	-6376.	0.	257.03
25.00	-4812.	-6104.	9.3280E+08	286.37
24.00	-10769.	-5803.	1.8573E+09	315.70
23.00	-16409.	-5473.	2.7633E+09	345.04
22.00	-21705.	-5113.	3.6409E+09	374.37
21.00	-26628.	-4730.	4.4811E+09	392.81
20.00	-31158.	-4328.	5.2754E+09	411.25
19.00	-35277.	-3907.	6.0158E+09	429.69
18.00	-38967.	-3468.	6.6954E+09	448.13
17.00	-42208.	-3011.	7.3077E+09	466.57
16.00	-44983.	-2535.	7.8471E+09	485.01
15.00	-47272.	-2041.	8.3089E+09	503.45
14.00	-49058.	-1528.	8.6890E+09	521.89
13.00	-50323.	-997.	8.9845E+09	540.33
12.00	-51047.	-448.	9.1931E+09	558.77
11.00	-51212.	120.	9.3135E+09	577.21
10.00	-50800.	707.	9.3456E+09	595.65
9.00	-49792.	1312.	9.2899E+09	614.09
8.00	-48170.	1935.	9.1483E+09	632.52
7.00	-45916.	2577.	8.9235E+09	650.96
6.00	-43011.	3237.	8.6195E+09	669.40
5.00	-39436.	3915.	8.2413E+09	687.84
4.00	-35174.	4613.	7.7950E+09	706.28
3.00	-30205.	5328.	7.2880E+09	724.72
2.00	-24511.	6062.	6.7290E+09	743.16
1.00	-18075.	6814.	6.1277E+09	761.60

Figure 52. Complete results for fixed earth method
for Example ANCH1 (Continued)

0.00	-10876.	7585.	5.4953E+09	780.04
-1.00	-2961.	8185.	4.8442E+09	419.83
-2.00	5374.	8425.	4.1880E+09	59.61
-2.17	6768.	8430.	4.0799E+09	0.00
-3.00	13768.	8304.	3.5411E+09	-300.60
-4.00	21862.	7824.	2.9180E+09	-660.81
-5.00	29296.	6983.	2.3326E+09	-1021.03
-6.00	35708.	5782.	1.7976E+09	-1381.24
-7.00	40739.	4220.	1.3241E+09	-1741.45
-8.00	44028.	2299.	9.2082E+08	-2101.67
-9.00	45216.	17.	5.9328E+08	-2461.88
-10.00	43942.	-2625.	3.4353E+08	-2822.09
-11.00	39846.	-5627.	1.6929E+08	-3182.31
-12.00	32567.	-8990.	6.3455E+07	-3542.52
-13.00	21746.	-12712.	1.3384E+07	-3902.73
-14.00	7023.	-16795.	3.2791E+05	-4262.95
-14.40	0.	-18519.	0.	-4406.24

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 52. (Concluded)

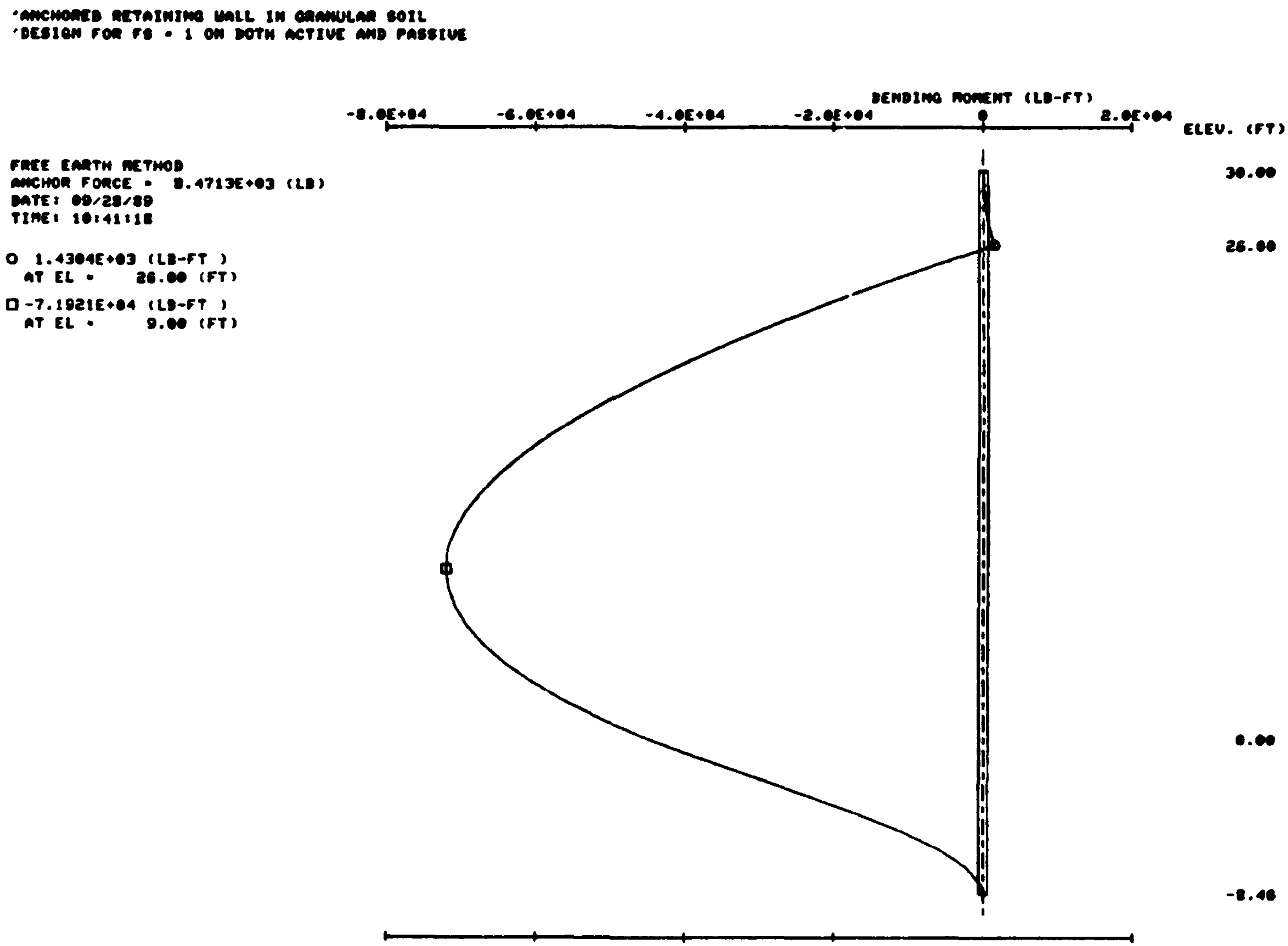


Figure 53. Bending moment for free earth method for Example ANCH1

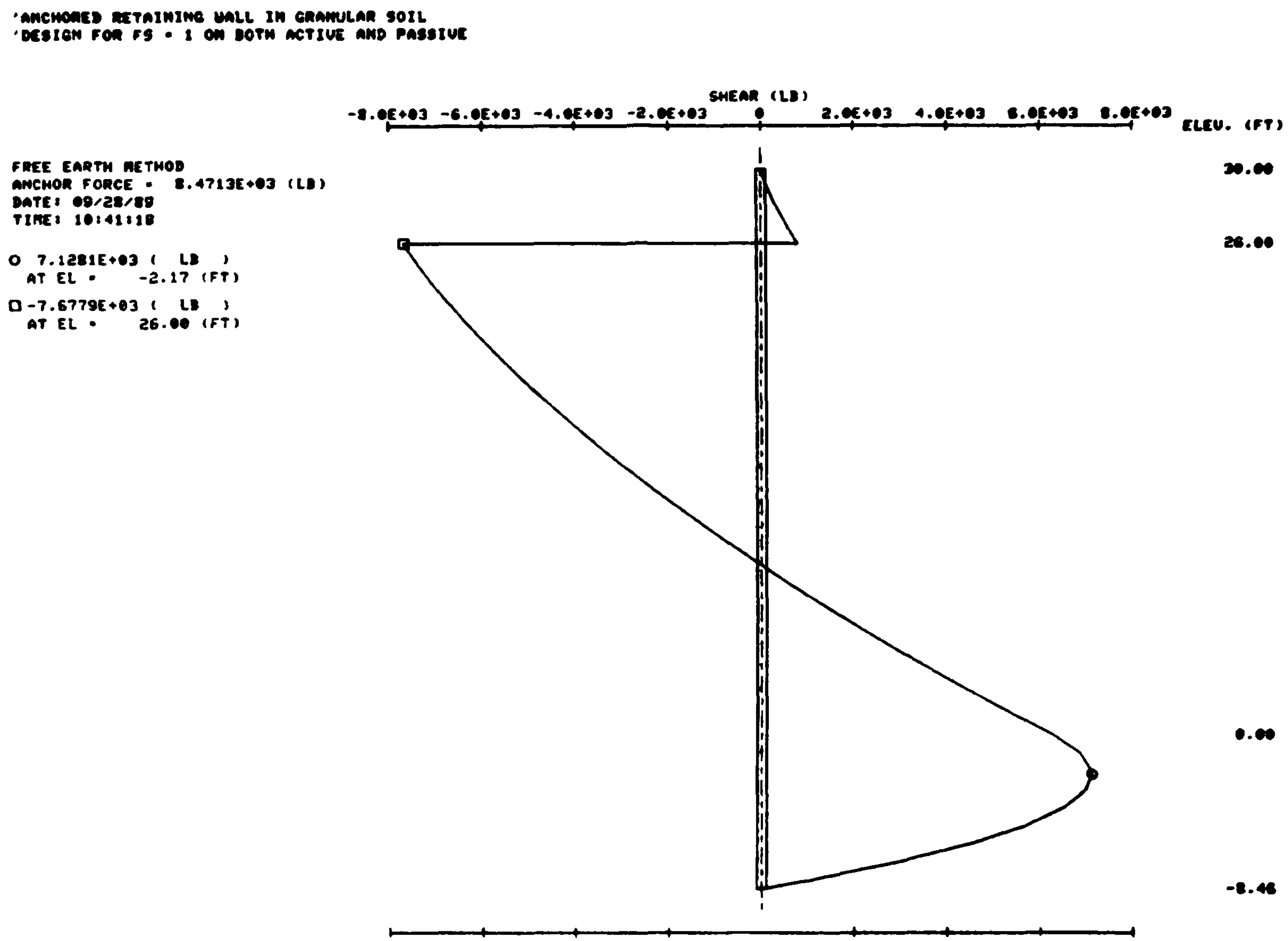


Figure 54. Shear for free earth method for Example ANCH1

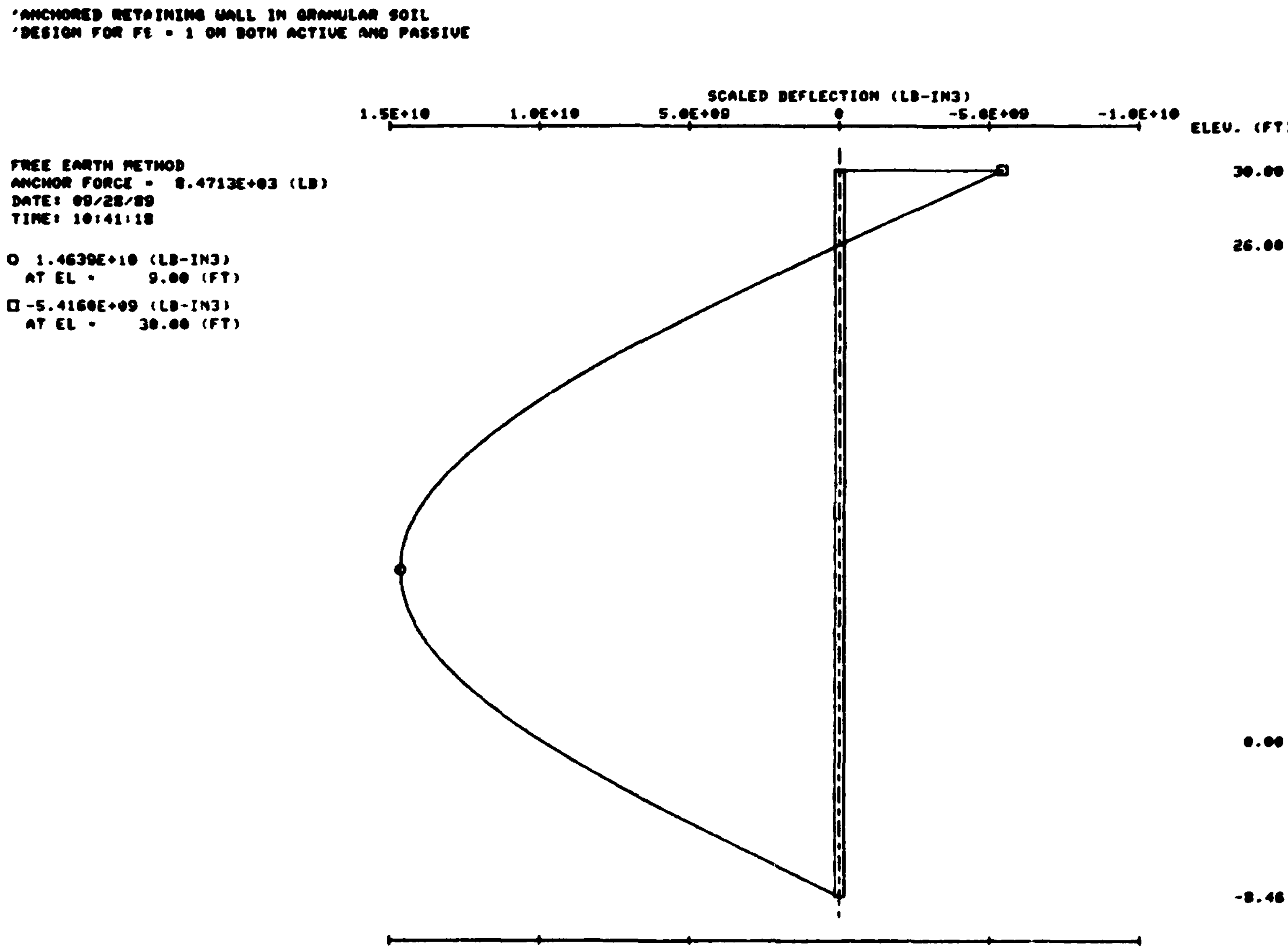


Figure 55. Scaled deflections for free earth method for Example ANCH1

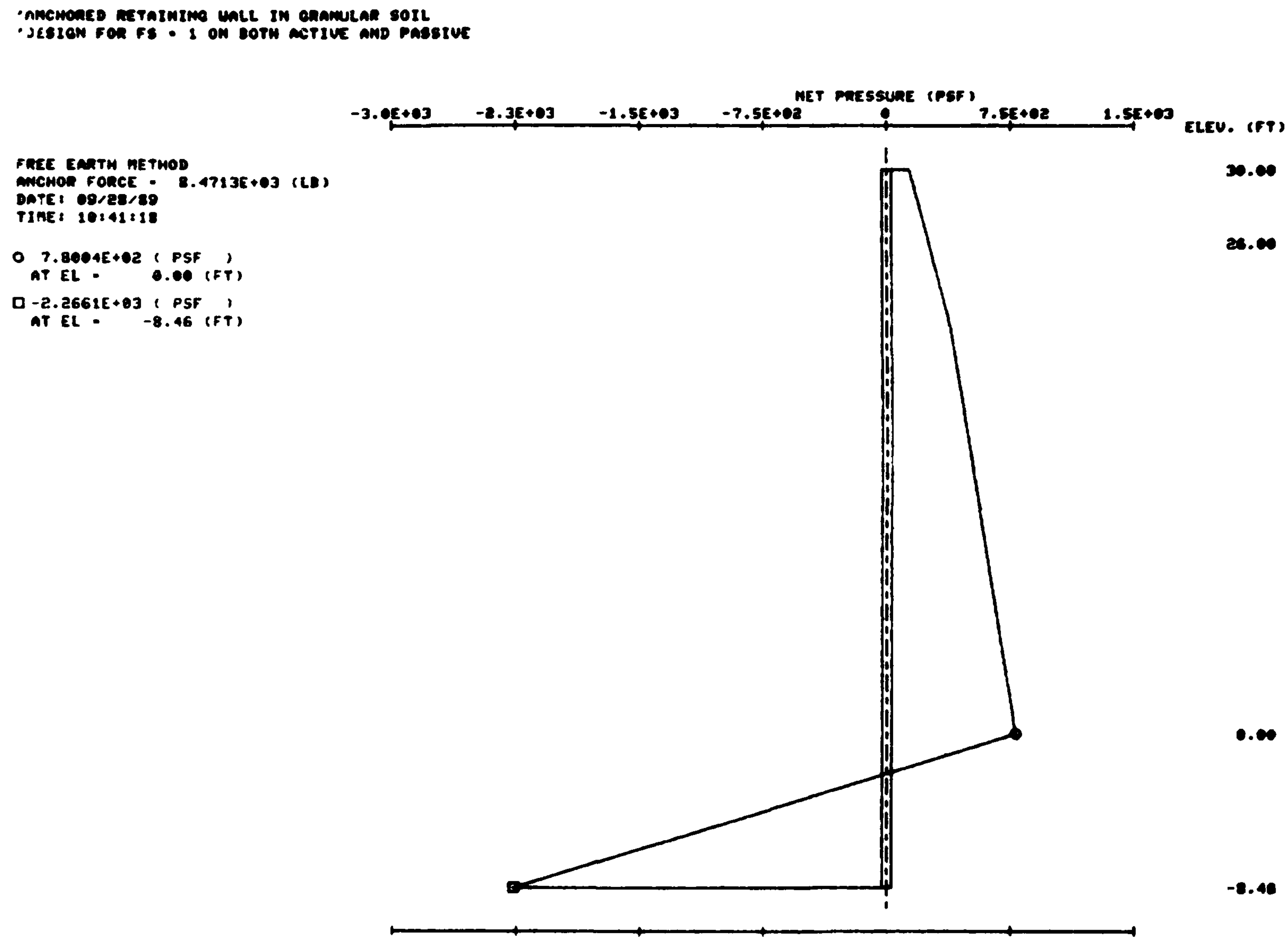


Figure 56. Net pressures for free earth method for Example ANCH1

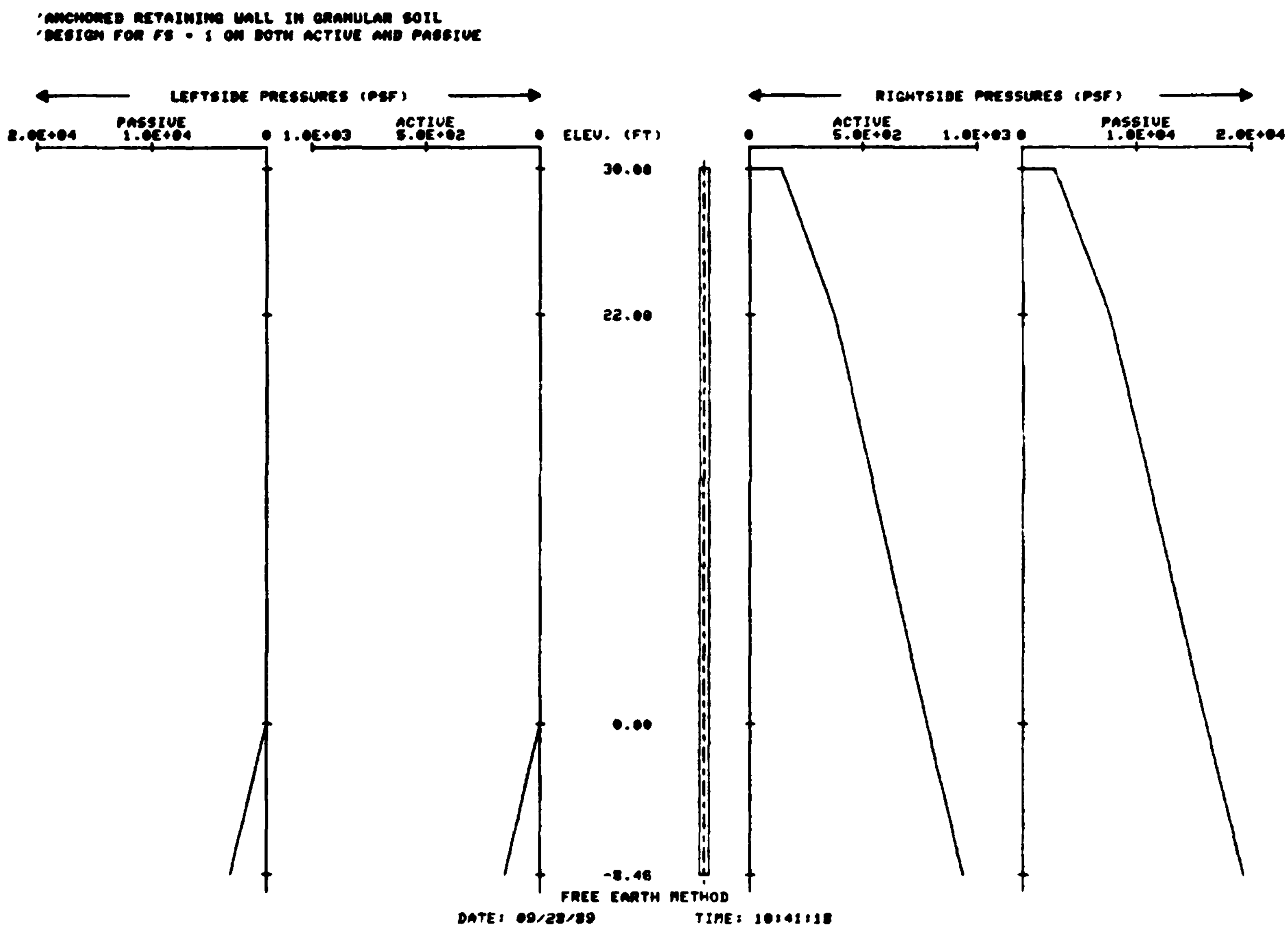


Figure 57. Active and passive soil pressures for free earth method for Example ANCH1

Example ANCH2

88. The anchored wall shown in Figure 58 was designed using the automatic seepage option. The input file and echoprint of input for this system are given in Figures 59 and 60. The initial soil pressures, Figure 61, are obtained for a beginning trial seepage gradient of 0.0001. Because the design depth of penetration is different for each anchored wall method, the final seepage gradient and, hence, final design pressures will be unique for each procedure.

89. The summary of results, Figure 62, presents the design parameters obtained for each method. Complete results and final design soil pressures for the free earth method are shown in Figures 63 and 64. Similar results as well as graphical output may be selected for any or all of the three methods employed for anchored wall design.

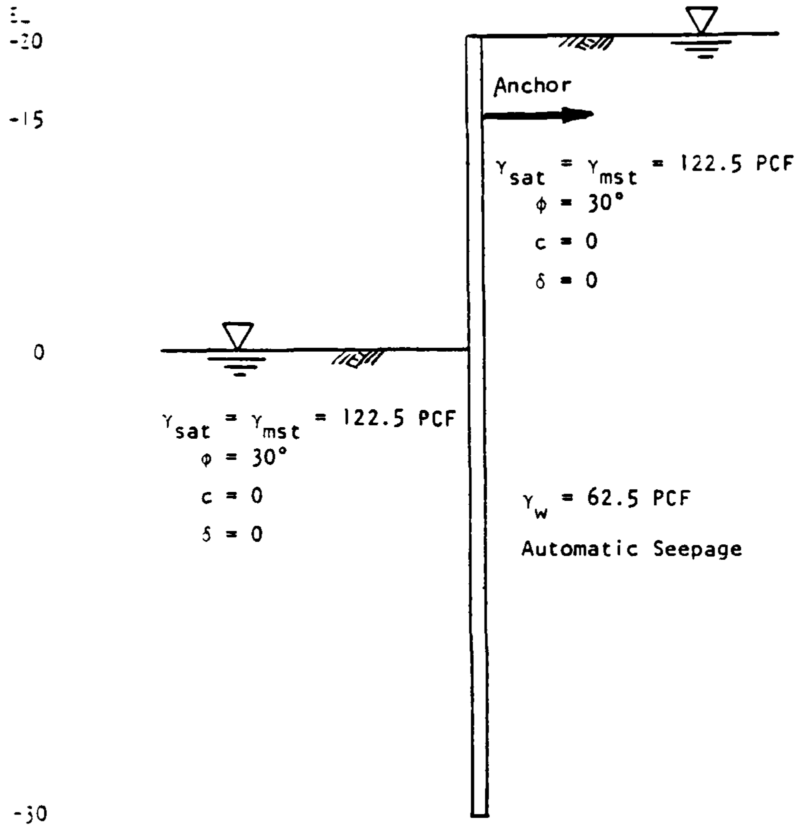


Figure 58. System for Example ANCH2

```
1000 'ANCHORED RETAINING WALL IN GRANULAR SOIL
1010 'WITH AUTOMATIC SEEPAGE
1020 C A D 1
1030 WALL 20 15
1030 SUR R 1 0 20
1040 SUR L 1 0 0
1050 SOIL BOTH S 1
1060 122.5 122.5 30 0 0 0
1070 WATER E 62.5 20 0 0 AUTOMATIC
1080 FINISH
```

Figure 59. Input file for Example ANCH2

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                             BY CLASSICAL METHODS
DATE: 08/25/89                                                  TIME: 08:57:33
                               ****************
                               *  INPUT DATA  *
                               ****************
I.--HEADING:
  'ANCHORED RETAINING WALL IN GRANULAR SOIL
  'WITH AUTOMATIC SEEPAGE
II.--CONTROL
  ANCHORED   WALL DESIGN
  LEVEL 1 FACTOR OF SAFETY FOR ACTIVE PRESSURES  = 1.00
  LEVEL 1 FACTOR OF SAFETY FOR PASSIVE PRESSURES = 1.00
III.--WALL DATA
  ELEVATION AT TOP OF WALL     =     20.00 (FT)
  ELEVATION AT ANCHOR          =     15.00 (FT)
IV.--SURFACE POINT DATA
  IV.A--RIGHTSIDE
     DIST. FROM     ELEVATION
     WALL (FT)        (FT)
           0.00       20.00
  IV.B-- LEFTSIDE
     DIST. FROM     ELEVATION
     WALL (FT)        (FT)
           0.00        0.00
V.--SOIL LAYER DATA
  V.A.--RIGHTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT
            ANGLE OF          ANGLE OF                         <-SAFETY->
 SAT.   MOIST  INTERNAL   COH-    WALL       ADH-     <--BOTTOM--> <-FACTOR->
WGHT.   WGHT.  FRICTION   ESION  FRICTION    ESION    ELEV.  SLOPE ACT. PASS.
(PCF)   (PCF)    (DEG)    (PSF)    (DEG)     (PSF)    (FT) (FT/FT)
122.50  122.50    30.00     0.0     0.00      0.0                   DEF   DEF
  V.B.-- LEFTSIDE LAYER DATA
     LEVEL 2 FACTOR OF SAFETY FOR ACTIVE PRESSURES  =  DEFAULT
     LEVEL 2 FACTOR OF SAFETY FOR PASSIVE PRESSURES =  DEFAULT
            ANGLE OF          ANGLE OF                         <-SAFETY->
 SAT.   MOIST  INTERNAL   COH-    WALL       ADH-     <--BOTTOM--> <-FACTOR->
WGHT.   WGHT.  FRICTION   ESION  FRICTION    ESION    ELEV.  SLOPE ACT. PASS.
(PCF)   (PCF)    (DEG)    (PSF)    (DEG)     (PSF)    (FT) (FT/FT)
122.50  122.50    30.00     0.0     0.00      0.0                   DEF   DEF
VI.--WATER DATA
     UNIT WEIGHT          =    62.50 (PCF)
     RIGHTSIDE ELEVATION =    20.00 (FT)
      LEFTSIDE ELEVATION =     0.00 (FT)
     SEEPAGE ELEVATION    =     0.00 (FT)
     SEEPAGE GRADIENT     =    AUTOMATIC
VII.--SURFACE LOADS
     NONE
VIII.--HORIZONTAL LOADS
     NONE
```

Figure 60. Echoprint of input data for Example ANCH2

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/25/89 TIME: 08:57:42

```
****************************
*    SOIL PRESSURES FOR    *
*   ANCHORED WALL DESIGN   *
****************************
```

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'WITH AUTOMATIC SEEPAGE

II.--SOIL PRESSURES

RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

```
**********************************************************
SOIL PRESSURES ARE REPORTED FOR A SEEPAGE GRADIENT =  .0001
AND MAY CHANGE WITH AUTOMATIC ADJUSTMENT OF THE GRADIENT.
**********************************************************
```

	<-LEFTSIDE PRESSURES->		<---NET PRESSURES----> (SOIL PLUS WATER)	<RIGHTSIDE PRESSURES->	
ELEV. (FT)	PASSIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	ACTIVE (PSF)	PASSIVE (PSF)
20.00	0.	0.	0.	0.	0.
19.00	0.	0.	8.250E+01	2.000E+01	1.800E+02
18.00	0.	0.	1.650E+02	4.000E+01	3.600E+02
17.00	0.	0.	2.475E+02	6.000E+01	5.400E+02
16.00	0.	0.	3.300E+02	8.000E+01	7.200E+02
15.00	0.	0.	4.125E+02	1.000E+02	9.000E+02
14.00	0.	0.	4.950E+02	1.200E+02	1.080E+03
13.00	0.	0.	5.775E+02	1.400E+02	1.260E+03
12.00	0.	0.	6.600E+02	1.600E+02	1.440E+03
11.00	0.	0.	7.425E+02	1.800E+02	1.620E+03
10.00	0.	0.	8.250E+02	2.000E+02	1.800E+03
9.00	0.	0.	9.075E+02	2.200E+02	1.980E+03
8.00	0.	0.	9.900E+02	2.400E+02	2.160E+03
7.00	0.	0.	1.073E+03	2.600E+02	2.340E+03
6.00	0.	0.	1.155E+03	2.800E+02	2.520E+03
5.00	0.	0.	1.238E+03	3.000E+02	2.700E+03
4.00	0.	0.	1.320E+03	3.200E+02	2.880E+03
3.00	0.	0.	1.403E+03	3.400E+02	3.060E+03
2.00	0.	0.	1.485E+03	3.600E+02	3.240E+03
1.00	0.	0.	1.568E+03	3.800E+02	3.420E+03

Figure 61. Initial soil pressure for Example ANCH2 (Sheet 1 of 3)

0.00	0.	0.	1.650E+03	4.000E+02	3.600E+03
-1.00	1.800E+02	2.000E+01	1.490E+03	4.200E+02	3.780E+03
-2.00	3.600E+02	4.000E+01	1.330E+03	4.400E+02	3.960E+03
-3.00	5.399E+02	5.999E+01	1.170E+03	4.600E+02	4.140E+03
-4.00	7.199E+02	7.999E+01	1.010E+03	4.800E+02	4.320E+03
-5.00	8.999E+02	9.999E+01	8.500E+02	5.000E+02	4.500E+03
-6.00	1.080E+03	1.200E+02	6.901E+02	5.200E+02	4.680E+03
-7.00	1.260E+03	1.400E+02	5.301E+02	5.400E+02	4.860E+03
-8.00	1.440E+03	1.600E+02	3.701E+02	5.600E+02	5.040E+03
-9.00	1.620E+03	1.800E+02	2.101E+02	5.800E+02	5.220E+03
-10.00	1.800E+03	2.000E+02	5.008E+01	6.000E+02	5.400E+03
-10.31	1.856E+03	2.062E+02	0.	6.063E+02	5.457E+03
-11.00	1.980E+03	2.200E+02	-1.099E+02	6.200E+02	5.580E+03
-12.00	2.160E+03	2.400E+02	-2.699E+02	6.400E+02	5.760E+03
-13.00	2.340E+03	2.600E+02	-4.299E+02	6.600E+02	5.940E+03
-14.00	2.520E+03	2.800E+02	-5.899E+02	6.800E+02	6.120E+03
-15.00	2.700E+03	3.000E+02	-7.499E+02	7.000E+02	6.300E+03
-16.00	2.880E+03	3.200E+02	-9.099E+02	7.200E+02	6.480E+03
-17.00	3.060E+03	3.400E+02	-1.070E+03	7.400E+02	6.660E+03
-18.00	3.240E+03	3.600E+02	-1.230E+03	7.600E+02	6.840E+03
-19.00	3.420E+03	3.800E+02	-1.390E+03	7.800E+02	7.020E+03
-20.00	3.600E+03	4.000E+02	-1.550E+03	8.000E+02	7.200E+03
-21.00	3.780E+03	4.200E+02	-1.710E+03	8.200E+02	7.380E+03
-22.00	3.960E+03	4.400E+02	-1.870E+03	8.400E+02	7.560E+03
-23.00	4.140E+03	4.600E+02	-2.030E+03	8.600E+02	7.740E+03
-24.00	4.320E+03	4.800E+02	-2.190E+03	8.801E+02	7.920E+03
-25.00	4.500E+03	4.999E+02	-2.350E+03	9.001E+02	8.100E+03
-26.00	4.680E+03	5.199E+02	-2.510E+03	9.201E+02	8.280E+03
-27.00	4.859E+03	5.399E+02	-2.670E+03	9.401E+02	8.461E+03
-28.00	5.039E+03	5.599E+02	-2.830E+03	9.601E+02	8.641E+03
-29.00	5.219E+03	5.799E+02	-2.990E+03	9.801E+02	8.821E+03
-30.00	5.399E+03	5.999E+02	-3.150E+03	1.000E+03	9.001E+03
-31.00	5.579E+03	6.199E+02	-3.310E+03	1.020E+03	9.181E+03
-32.00	5.759E+03	6.399E+02	-3.470E+03	1.040E+03	9.361E+03
-33.00	5.939E+03	6.599E+02	-3.630E+03	1.060E+03	9.541E+03
-34.00	6.119E+03	6.799E+02	-3.790E+03	1.080E+03	9.721E+03
-35.00	6.299E+03	6.999E+02	-3.950E+03	1.100E+03	9.901E+03
-36.00	6.479E+03	7.199E+02	-4.110E+03	1.120E+03	1.008E+04
-37.00	6.659E+03	7.399E+02	-4.270E+03	1.140E+03	1.026E+04
-38.00	6.839E+03	7.599E+02	-4.430E+03	1.160E+03	1.044E+04
-39.00	7.019E+03	7.799E+02	-4.590E+03	1.180E+03	1.062E+04
-40.00	7.199E+03	7.999E+02	-4.750E+03	1.200E+03	1.080E+04
-41.00	7.379E+03	8.199E+02	-4.910E+03	1.220E+03	1.098E+04
-42.00	7.559E+03	8.399E+02	-5.070E+03	1.240E+03	1.116E+04
-43.00	7.739E+03	8.599E+02	-5.230E+03	1.260E+03	1.134E+04
-44.00	7.919E+03	8.799E+02	-5.390E+03	1.280E+03	1.152E+04

Figure 61. (Sheet 2 of 3)

-45.00	8.099E+03	8.999E+02	-5.550E+03	1.300E+03	1.170E+04
-46.00	8.279E+03	9.199E+02	-5.710E+03	1.320E+03	1.188E+04
-47.00	8.459E+03	9.399E+02	-5.870E+03	1.340E+03	1.206E+04
-48.00	8.639E+03	9.599E+02	-6.030E+03	1.360E+03	1.224E+04
-49.00	8.819E+03	9.799E+02	-6.190E+03	1.380E+03	1.242E+04
-50.00	8.999E+03	9.999E+02	-6.350E+03	1.400E+03	1.260E+04
-51.00	9.179E+03	1.020E+03	-6.510E+03	1.420E+03	1.278E+04
-52.00	9.359E+03	1.040E+03	-6.670E+03	1.440E+03	1.296E+04
-53.00	9.539E+03	1.060E+03	-6.830E+03	1.460E+03	1.314E+04
-54.00	9.719E+03	1.080E+03	-6.990E+03	1.480E+03	1.332E+04
-55.00	9.899E+03	1.100E+03	-7.150E+03	1.500E+03	1.350E+04
-56.00	1.008E+04	1.120E+03	-7.310E+03	1.520E+03	1.368E+04
-57.00	1.026E+04	1.140E+03	-7.470E+03	1.540E+03	1.386E+04
-58.00	1.044E+04	1.160E+03	-7.630E+03	1.560E+03	1.404E+04
-59.00	1.062E+04	1.180E+03	-7.790E+03	1.580E+03	1.422E+04
-60.00	1.080E+04	1.200E+03	-7.950E+03	1.600E+03	1.440E+04
-61.00	1.098E+04	1.220E+03	-8.109E+03	1.620E+03	1.458E+04

Figure 61. (Sheet 3 of 3)

```
PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
                          BY CLASSICAL METHODS
DATE: 08/25/89                                                TIME: 08:58:38

                        ****************************
                        *  SUMMARY OF RESULTS FOR  *
                        *   ANCHORED WALL DESIGN   *
                        ****************************

I.--HEADING

  'ANCHORED RETAINING WALL IN GRANULAR SOIL
  'WITH AUTOMATIC SEEPAGE

II.--SUMMARY


     RIGHTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

      LEFTSIDE SOIL PRESSURES DETERMINED BY COULOMB COEFFICIENTS
     AND THEORY OF ELASTICITY EQUATIONS FOR SURCHARGE LOADS.

METHOD                     :   FREE EARTH     EQUIV. BEAM     FIXED EARTH

WALL BOTTOM ELEV. (FT)     :       -25.24          -35.17          -33.17
      PENETRATION (FT)     :        25.24           35.17           33.17

MAX. BEND. MOMENT (LB-FT)  :     -155632.        -107284.        -122038.
      AT ELEVATION (FT)    :        -1.00            1.00            1.00

MAX. SCALED DEFL. (LB-IN3) :   3.9502E+10     -1.3715E+10      2.6013E+10
      AT ELEVATION (FT)    :        -4.00          -26.00           -2.00

ANCHOR FORCE (LB)          :       17684.          14400.          15453.

SEEPAGE GRADIENT           :        .3956           .2841           .3011


     (NOTE: PENETRATION FOR EQUIVALENT BEAM
     METHOD DOES NOT INCLUDE INCREASE
     PRESCRIBED BY DRAFT EM 1110-2-2906.)

     (NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
     ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
     IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)
```

Figure 62. Summary of results for Example ANCH2

PROGRAM CWALSHT-DESIGN/ANALYSIS OF ANCHORED OR CANTILEVER SHEET PILE WALLS
BY CLASSICAL METHODS

DATE: 08/25/89 TIME: 08:58:38

```
****************************
*   COMPLETE RESULTS FOR   *
*   ANCHORED WALL DESIGN   *
*   BY FREE EARTH METHOD   *
****************************
```

I.--HEADING

'ANCHORED RETAINING WALL IN GRANULAR SOIL
'WITH AUTOMATIC SEEPAGE

II.--RESULTS (ANCHOR FORCE = 17684. (LB))

ELEVATION (FT)	BENDING MOMENT (LB-FT)	SHEAR (LB)	SCALED DEFLECTION (LB-IN3)	NET PRESSURE (PSF)
20.00	0.	0.	-1.7104E+10	0.00
19.00	14.	41.	-1.3684E+10	82.50
18.00	110.	165.	-1.0264E+10	165.00
17.00	371.	371.	-6.8436E+09	247.50
16.00	880.	660.	-3.4226E+09	330.00
15.00	1719.	1031.	0.	412.50
15.00	1719.	-16652.	0.	412.50
14.00	-14713.	-16198.	3.4205E+09	495.00
13.00	-30651.	-15662.	6.8156E+09	577.50
12.00	-46010.	-15043.	1.0158E+10	660.00
11.00	-60710.	-14342.	1.3421E+10	742.50
10.00	-74667.	-13558.	1.6579E+10	825.00
9.00	-87800.	-12692.	1.9608E+10	907.50
8.00	-100024.	-11743.	2.2486E+10	990.00
7.00	-111259.	-10712.	2.5190E+10	1072.50
6.00	-121421.	-9598.	2.7703E+10	1155.00
5.00	-130428.	-8402.	3.0006E+10	1237.50
4.00	-138198.	-7123.	3.2084E+10	1320.00
3.00	-144648.	-5762.	3.3923E+10	1402.50
2.00	-149695.	-4318.	3.5513E+10	1485.00
1.00	-153257.	-2792.	3.6844E+10	1567.50
0.00	-155252.	-1183.	3.7911E+10	1650.00
-1.00	-155632.	403.	3.8709E+10	1522.96
-2.00	-154488.	1862.	3.9239E+10	1395.93
-3.00	-151949.	3195.	3.9502E+10	1268.89
-4.00	-148141.	4400.	3.9502E+10	1141.85
-5.00	-143191.	5479.	3.9247E+10	1014.81
-6.00	-137226.	6430.	3.8745E+10	887.78
-7.00	-130374.	7254.	3.8005E+10	760.74
-8.00	-122760.	7951.	3.7040E+10	633.70
-9.00	-114513.	8522.	3.5864E+10	506.66

Figure 63. Complete results for free earth method for Example ANCH2 (Continued)

-10.00	-105760.	8965.	3.4489E+10	379.63
-11.00	-96626.	9281.	3.2932E+10	252.59
-12.00	-87240.	9470.	3.1208E+10	125.55
-12.99	-77840.	9532.	2.9355E+10	0.00
-12.99	-77840.	9531.	2.9355E+10	0.00
-13.00	-77729.	9530.	2.9333E+10	-1.48
-13.00	-77729.	9532.	2.9333E+10	-1.48
-14.00	-68219.	9467.	2.7324E+10	-128.52
-15.00	-58838.	9275.	2.5196E+10	-255.56
-16.00	-49713.	8955.	2.2968E+10	-382.60
-17.00	-40970.	8509.	2.0653E+10	-509.63
-18.00	-32736.	7936.	1.8267E+10	-636.67
-19.00	-25140.	7236.	1.5825E+10	-763.71
-20.00	-18307.	6409.	1.3339E+10	-890.75
-21.00	-12364.	5454.	1.0821E+10	-1017.78
-22.00	-7440.	4373.	8.2821E+09	-1144.82
-23.00	-3660.	3165.	5.7300E+09	-1271.86
-24.00	-1153.	1829.	3.1713E+09	-1398.89
-25.00	-44.	367.	6.1042E+08	-1525.93
-25.24	0.	0.	0.	-1556.21

(NOTE: DIVIDE SCALED DEFLECTION BY MODULUS OF
ELASTICITY IN PSI TIMES PILE MOMENT OF INERTIA
IN IN**4 TO OBTAIN DEFLECTION IN INCHES.)

Figure 63. (Concluded)

IV.--SOIL PRESSURES

ELEVATION (FT)	< LEFTSIDE PRESSURE (PSF)> PASSIVE	ACTIVE	<RIGHTSIDE PRESSURE (PSF)> ACTIVE	PASSIVE
20.00	0.	0.	0.	0.
19.00	0.	0.	20.	180.
18.00	0.	0.	40.	360.
17.00	0.	0.	60.	540.
16.00	0.	0.	80.	720.
15.00	0.	0.	100.	900.
14.00	0.	0.	120.	1080.
13.00	0.	0.	140.	1260.
12.00	0.	0.	160.	1440.
11.00	0.	0.	180.	1620.
10.00	0.	0.	200.	1800.
9.00	0.	0.	220.	1980.
8.00	0.	0.	240.	2160.
7.00	0.	0.	260.	2340.
6.00	0.	0.	280.	2520.
5.00	0.	0.	300.	2700.
4.00	0.	0.	320.	2880.
3.00	0.	0.	340.	3060.
2.00	0.	0.	360.	3240.
1.00	0.	0.	380.	3420.
0.00	0.	0.	400.	3600.
-1.00	106.	12.	428.	3854.
-2.00	212.	24.	456.	4108.
-3.00	318.	35.	485.	4362.
-4.00	423.	47.	513.	4617.
-5.00	529.	59.	541.	4871.
-6.00	635.	71.	569.	5125.
-7.00	741.	82.	598.	5379.
-8.00	847.	94.	626.	5633.
-9.00	953.	106.	654.	5887.
-10.00	1058.	118.	682.	6142.
-11.00	1164.	129.	711.	6396.
-12.00	1270.	141.	739.	6650.
-12.99	1375.	153.	767.	6901.
-13.00	1376.	153.	767.	6904.
-14.00	1482.	165.	795.	7158.
-15.00	1588.	176.	824.	7412.
-16.00	1693.	188.	852.	7667.
-17.00	1799.	200.	880.	7921.
-18.00	1905.	212.	908.	8175.
-19.00	2011.	223.	937.	8429.
-20.00	2117.	235.	965.	8683.
-21.00	2223.	247.	993.	8937.
-22.00	2328.	259.	1021.	9192.
-23.00	2434.	270.	1050.	9446.
-24.00	2540.	282.	1078.	9700.
-25.00	2646.	294.	1106.	9954.
-25.28	2676.	297.	1114.	10026.

Figure 64. Final soil pressures for free earth method for Example ANCH2

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APPENDIX A: GUIDE FOR DATA INPUT

Source of Input

1. Input data may be supplied from a predefined data file or from the user terminal during execution. If data are supplied from the user terminal, prompting messages are printed to indicate the amount and character of data to be entered.

Data Editing

2. When all data for a problem have been entered, the user is offered the opportunity to review an echoprint of the currently available input data and to revise any or all sections of the input data before execution is attempted. When editing is performed during execution, each section must be entered in its entirety.

Input Data File Generation

3. After data have been entered from the terminal, either initially or after editing, the user may direct the program to write the input data to a permanent file in input data file format.

Data Format

4. All input data (whether supplied from the user terminal or from a file) are read in free-field format:

a. Data items must be separated by one or more blanks (COMMA SEPARATORS ARE NOT PERMITTED).

b. Integer numbers must be of form NNNN.

c. Real numbers may be of form

±xxxx, ±xx.xx, or ±xx.xxE+ee

d. User responses to all requests for control by the program for alphanumeric input may be abbreviated by the first letter of the indicated word response, e.g.,

ENTER 'YES' OR 'NO'--respond Y or N

ENTER 'CONTINUE' OR 'END'--respond C or E

Sections of Input

5. Input data are divided into the following sections:

I. HEADING (Required).

II. CONTROL (Required).

III. WALL DATA (Required).

IV. SOIL SURFACE DATA (Required).

V. SOIL PROFILE DATA (Required).

VI. WATER DATA (Optional).

VII. VERTICAL LOAD DATA (Optional).

VIII. HORIZONTAL LOAD DATA (Optional).

IX. TERMINATION (Required).

Units

6. The program expects data to be provided in units of inches, feet, or pounds as noted in the guide that follows. No provision is made for conversion to other systems of units by the program.

Predefined Data File

7. In addition to the general format requirements given in paragraph 4 of Appendix A, the following items pertain to a predefined data file and to the input data description which follows:

a. Each line must commence with a nonzero, positive line number, denoted LN.

b. A line of input may require both alphanumeric and numeric data items. Alphanumeric data items are enclosed in single quotes in the following paragraphs.

c. A line of input may require a keyword. The acceptable abbreviation for the keyword is indicated by underlined capital letters, e.g., the acceptable abbreviation for the keyword '<u>SU</u>rface' is 'SU'.

d. Lower case words in single quotes indicate that a choice of keywords defined follows.

e. Items designated by upper case letters and numbers without quotes indicate numeric data values. Numeric data values are either real or integer according to standard FORTRAN variable naming conventions.

f. Data items enclosed in brackets [ ] may not be required. Data items enclosed in braces { } indicate special note follows.

g. Input data are divided into the sections discussed in this appendix, paragraph 5. Except for the heading, each section consists of a header line and one or more data lines.

h. Comment lines may be inserted in the input file by enclosing the line, following the line number, in parentheses. Comment lines are ignored, e.g.,

1234ƀ (THIS LINE IS IGNORED).

Sequence of Solutions

8. A predefined data file may contain a sequence of input data sets to be run in succession. The first data set must contain all required data (from HEADING through TERMINATION) for the problem. Subsequent data sets may contain an independent problem or may contain data which amend existing input data.

General Discussion of Input Data

9. Each data section contains a descriptor ('side') to indicate the side of the system to which the data apply. For symmetric effects ('side' = 'Both'), the data section is entered only once and symmetric data are applied to both sides automatically. For unsymmetric conditions, the description for the right side (if present) must be entered first and must be immediately followed by the description for the left side (if present).

10. Rightside and leftside descriptions must be supplied either explicitly or implicitly (i.e., 'side' = 'Both') for surface points and soil profile data sections. Other data may be supplied either for the right side or left side, or both, or may be omitted entirely.

Input Description

11. HEADING--One (1) to four (4) lines

a. Line contents

LN 'heading'

b. Definition

'heading' = any alphanumeric information up to 70 characters including LN and any embedded blanks; first nonblank character following LN must be a single quote (').

12. CONTROL--One (1) line

a. Line contents

LN 'Control' 'type' 'mode' [FSA1 [FSP1]]

b. Definitions

'Control' = section title.

'type' = 'Cantilever' or 'Anchored'.

'mode' = 'Analysis' or 'Design'.

[FSA1] = factor of safety to be applied for active earth pressures; assumed to be one if omitted if 'mode' = Design.

[FSP1] = factor of safety to be applied for passive earth pressures; assumed to be equal to FSA1 if omitted and 'mode' = 'Design'; omit if FSA1 is omitted; omit if 'mode' = 'Analysis'.

c. Discussion

(1) In the 'Design' mode, FSA1 and FSP1 are the default factors of safety to be applied to all soil layers on each side of the wall unless overridden in subsequent data.

(2) In the 'Analysis' mode:

(a) If both FSA1 and FSP1 are omitted, a single factor of safety is determined and applied for active and passive pressures. Any subsequent factors of safety are ignored.

(b) If FSA1 is supplied, the input value is the default factor of safety to be applied to all soil layers on each side of the wall unless overridden in subsequent data. The program determines the value of FSP1.

13. WALL DATA--One (1) line

a. Line contents

LN 'WAll' ELTOP [ELANCH] [ELBOT WALLE WALLI]

b. Definitions

'WAll' = section title.

ELTOP = elevation (FT) at top of wall.

[ELANCH] = elevation (FT) at anchor; omit if 'type' = 'Cantilever'.

[ELBOT] = elevation (FT) at bottom of wall; omit if 'mode' = 'Design'.

[WALLE] = Modulus of elasticity (PSI) of wall; omit if 'mode' = 'Design'.

[WALLI] = wall moment of inertia ($IN.^4$) per foot of wall; omit if 'mode' = 'Design'.

14. SOIL SURFACE DATA--One (1) or more lines

a. Line contents

LN 'SUrface' ('side') NSUR DSUR(1) ELSUR(1)

[----- DSUR(n) ELSUR(n)]

b. Definitions

'SUrface' = section title

('side') = 'Leftside', 'Rightside', or 'Both'.

NSUR = number of surface points (1 to 15) on this ('side').

DSUR(i) = horizontal distance (FT) from wall to ith surface point.

ELSUR(i) = elevation (FT) at ith surface point.

c. Discussion

(1) If identical soil surfaces exist on each side of the wall, i.e., 'side' = 'Both', enter data for rightside surface. The program will generate a mirror image for the left side.

(2) At least one surface point must be provided. Up to 21 surface points are permitted. Pairs of DSUR(i) and ELSUR(i) may be continued on subsequent lines following a line number.

(3) If DSUR(1) is greater than zero, a horizontal surface is assumed at ELSUR(1) from the wall to a distance DSUR(1).

(4) ELSUR(1) must be less than or equal to ELTOP; ELSUR(1) must be greater than ELBOT if 'mode' = 'Analysis'.

(5) If more than one surface point is provided, a broken surface is assumed and soil pressures will be calculated by the wedge method. Distances and elevations must begin with the point nearest the wall and progress outward.

(6) If different surface conditions exist on each side, surface descriptions must be entered twice, once for the 'Rightside' and once for the 'Leftside'.

(7) The surface is assumed to extend horizontally ad infinitum at the elevation of the last point provided.

15. SOIL PROFILE DATA--Two (2) or more lines

a. Control--One (1) line

(1) Line contents

LN 'SOil' ('side') ('type') NLAY [FSA2 [FSP2]]

(2) Definitions

'SOil' = section title.

{'side'} = 'Rightside', 'Leftside', or 'Both'.

{'type'} = 'Strengths' if internal friction and/or soil cohesions and wall friction angles are provided. Required if {'mode'} = 'Analysis' or if a broken surface exists on this {'side'}.

= 'Coefficients' if active and passive pressure coefficients are provided. Not allowed if {'mode'} = 'Analysis or if broken surface exists on this {'side'}.

NLAY = number of soil layers (1 to 15) on this {'side'}.

[FSA2] = factor of safety for active pressures to be applied to all soil layers on this {'side'}; overrides FSA1; assumed to be equal to FSA1 if omitted or entered as zero. Omit if {'type'} = 'Coefficients'. Ignored for {'mode'} = 'Analysis' if FSA1 is omitted; ignored if {'type'} = 'Coefficients'.

[FSP2] = factor of safety for passive pressures to be applied to all soil layers on this {'side'}; overrides FSP1; assumed to be equal to FSP1 for 'Design' if omitted; omit if FSA2 is omitted; ignored if {'mode'} = 'Analysis'; ignored if {'type'} = 'Coefficients'.

b. Soil layer data for {'type'} = 'Strengths'--NLAY lines, one (1) line for each layer:

(1) Line contents

LN GAMSAT GAMMST PHI C DELTA ADH [ELLAYB SLOBOT]

[FSA3 [FSP3]]

(2) Definitions

GAMSAT = saturated unit weight (PCF) of soil (program subtracts unit weight of water from GAMSAT to obtain effective unit weight of submerged soil).

GAMMST = unit weight (PCF) of soil above water.

PHI = angle of internal friction (DEG).

C = cohesion (PSF).

DELTA = angle of wall friction (DEG).

ADH = unit wall/soil adhesion (PSF).

[ELLAYB] = Elevation (FT) at intersection of bottom of layer with wall; omit if last layer.

[SLOBOT] - slope (FT) of bottom of layer; interpreted as rise per foot horizontal; positive if layer boundary slopes upward; omit if last layer.

[FSA3] - factor of safety for active pressures to be applied to this layer; overrides FSA2; assumed to be equal to FSA2 if omitted or entered as zero; ignored if FSA1 is omitted for 'Analysis'.

[FSP3] - factor of safety for passive pressures to be applied to this layer; overrides FSP2; assumed to be equal to FSP2 if omitted; omit if FSA3 is omitted; ignored for ('mode') = 'Analysis'.

(3) Discussion

(a) At least one soil layer on each side of the wall is required. Up to 15 layers on each side of the wall are permitted.

(b) Soil layer data must commence with the top layer and proceed sequentially downward.

(c) The last soil layer on each side is assumed to extend ad infinitum downward.

(d) Both PHI and C cannot be zero for any layer.

(e) DELTA must be positive and less than PHI for each layer.

(f) ADH must be positive and less than C for each layer.

(g) Bottom slopes of adjacent soil layers must not intersect within the soil mass.

(h) Layer bottom elevations must conform to:

ELLAYB(1) ≤ ELTOP

ELLAYB(1) < ELSUR( )

ELLAYB(1) > ELBOT if ('mode') = 'Analysis'

ELLAYB(i) < ELLAYB(i-1)

(i) The program will generate identical soil layer descriptions for both sides of the wall if ('side') = 'Both'.

(j) If different soil profiles exist on each side of the wall, soil layer data must be entered twice, once for the 'Rightside' and once for the 'Leftside'.

(k) Layer data for ('type') = 'Strengths' must be available if ('mode') = 'Analysis'.

(l) If any soil layer boundary on either side has a nonzero slope, soil pressures on that side are calculated by the wedge method.

c. Soil layer data for ('type') = 'Coefficients'--NLAY lines, one (1) line for each layer

(1) Line contents

LN GAMSAT GAMMST AK PK [ELLAYB]

(2) Definitions

GAMSAT = saturated unit weight (PCF) of soil (program subtracts unit weight of water from GAMSAT to obtain effective unit weight of submerged soil).

GAMMST = unit weight of soil above water.

AK = active soil pressure coefficient.

PK = passive soil pressure coefficient.

[ELLAYB] = elevation (FT) at intersection of bottom layer with wall; omit if last layer.

(3) Discussion

(a) At least one soil layer on each side of wall. Up to 15 soil layers on each side of the wall are permitted.

(b) Soil layer data must commence with the top layer and proceed sequentially downward.

(c) The last soil layer is assumed to extend ad infinitum downward.

(d) Both AK and PK must be nonzero.

(e) Layer boundary elevations must conform to:

$ELLAYB(1) \leq ELTOP$

$ELLAYB(1) < ELLAYB(i-1)$

16. WATER DATA--Zero (0) or one (1) or more lines; entire section may be omitted; choose one, a or b, of the following:

a. Water elevations provided

(1) Line contents

LN 'WATer Elevations' GAMWAT ELWATR ELWATL [ELSEEP (seep spec)]

(2) Definitions

'WATer Elevations' = section title.

GAMWAT = unit weight (PCF) of water.

ELWATR = elevation (FT) of water surface on rightside.

ELWATL = elevation (FT) of water surface on leftside.

ELSEEP = elevation (FT) on rightside at which seepage commences; omit if seepage is not to be considered; omit if $ELWATR \leq ELWATL$.

{seep spec} = seepage gradient SEEP (FT/FT); 0 < SEEP < 1; omit if ELSEEP omitted.

= 'Automatic' if seepage gradient is to be determined by program to result in zero net water pressure at bottom of wall; omit if ELSEEP omitted.

(3) Discussion

(a) Effective soil unit weight for submerged soil is calculated in the program by subtracting the effective weight of water from the saturated unit weight of the soil.

(b) ELWATR and ELWATL must be less than or equal to ELTOP.

(c) Seepage effects cannot be included unless ELWATR > ELWATL.

(d) ELSEEP must conform to the following:

ELSEEP ≤ MIN (ELWATR, ELSUR (rightside 1))

ELSEEP ≥ MIN (ELWATL, ELSUR (leftside 1))

(e) If the seepage gradient, SEEP, is provided, the resulting net water pressure may not be zero at the bottom of the wall.

(f) If {seep specs} = 'Automatic' is specified, the seepage gradient is determined by the program to enforce zero net water pressure at the bottom of the wall.

(g) If seepage is to be considered for 'mode' = 'Analysis', ELWATL must be greater than ELBOT.

b. Net water pressures specified--One (1) or more lines

(1) Line contents

LN 'WATer Pressure' NWPR ELWPR(1) WPR(1)

ELWPR(2) WPR(2) . . . ELRPS(n) WPR(n)

(2) Definitions

'WATer Pressure' = section title.

NWPR = number (2 to 21) of points on water pressure distribution.

ELWPR(i) = elevation (FT) of ith pressure point.

WPR(i) = net water pressure at ith pressure point, positive to left.

(3) Discussion

(a) At least two (2) pressure points must be provided. A maximum of 21 pressure points is permitted. Pairs of ELWPR(i), WPR(i) may be continued on subsequent lines following a line number.

(b) Elevations must begin at uppermost point and proceed downward with:

$$ELWPR(1) \leq ELTOP$$

$$ELWPR(i) < ELWPR(i-1)$$

(c) Specified water pressures do not alter soil pressures. GAMMST is used for the effective weight of soil at all elevations on both sides of the wall.

17. VERTICAL LOADS ON SURFACE--Zero (0) or one (1) or more lines; entire section may be omitted.

a. Line loads--Zero (0) or one (1) or more lines

(1) Line contents

LN 'Vertical Line' {'side'} NVL DL(1) QL(1)

. . . DL(n) QL(n)

(2) Definitions

'Vertical Line' = subsection title.

NVL = number of line loads (1 to 21) on this {'side'}.

{'side'} = 'Rightside', 'Leftside', or 'Both'.

DL(i) = distance (FT) to line load.

QL(i) = magnitude (PLf) of line load; positive downward.

(3) Discussion

(a) If {'side'} = 'Both', mirror image line loads are generated on each side of the wall.

(b) Up to 21 line loads may be applied to the surface on each side of the wall.

(c) Pairs of DL(i), QL(i) may be continued on subsequent lines following a line number.

(d) DL(i) must be greater than zero.

(e) QL(i) must be greater than or equal to zero (i.e., upward loads are not permitted).

b. Distributed loads--Zero (0) or one (1) or more lines. Only one of the following distributed load types may be applied on either side of the wall:

(1) Uniform load--Zero (0) or one (1) line

(a) Line contents

LN 'Vertical Uniform' {'side'} QU

(b) Definitions

'Vertical Uniform' = subsection title.

{'side'} = 'Rightside', 'Leftside', or 'Both'.

QU = magnitude (PSF) of uniform load, positive downward.

(c) Discussion

1. A uniform load is interpreted as acting on the horizontal projection of the surface.

2. The uniform load extends to infinity away from the wall.

3. If {'side'} = 'Both', identical uniform loads are applied to the surface on each side of the wall.

4. QU must be greater than or equal to zero (i.e., upward load is not permitted).

(2) Strip loads--Zero (0) or one (1) or more lines

(a) Line contents

LN 'Vertical Strip' {'side'} NVS DS1(1) DS2(1) QS(1) [. . . DS1(n) DS2(n) QS(n)]

(b) Definitions

'Vertical Strip' = subsection title.

{'side'} = 'Rightside', 'Leftside', or 'Both'.

NVS = number (1 to 21) of strip loads.

DS1(i) = distance (FT) from wall to beginning of 'Strip' load.

DS2(i) = distance (FT) from wall to end of strip load.

QS(i) = magnitude (PSF) of strip load, positive downward.

(c) Discussion

1. A strip load is interpreted as acting on the horizontal projection of the surface.

2. Up to 21 strip loads may be applied on either side of the wall. Triads of DS1(i), QS(i), DS2(i) may be continued on subsequent lines following a line number.

3. QS(i) must be greater than or equal to zero (i.e., upward load is not permitted).

4. Distances must conform to:

   DS1(i) ≥ Zero

   DS2(i) > QS1(i)

5. If {'side'} = 'Both', mirror image strip loads are applied to the surface on each side of the wall.

(3) Ramp loads--Zero (0) or one (1) line

(a) Line contents

LN 'Vertical Ramp' {'side'} DR1 DR2 QR

(b) Definitions

'Vertical Ramp' = subsection title.

{'side'} = 'Rightside', 'Leftside', or 'Both'.

DR1 = distance (FT) from wall to beginning of ramp load.

DR2 = distance (FT) to end of ramp.

QR = magnitude (PSF) of uniform load extension of ramp load, positive downward.

(c) Discussion

1. A ramp load is interpreted as acting on the horizontal projection of the surface.

2. Only one ramp is permitted on each side of the wall.

3. Distances must conform to

$DR1 \geq Zero$

$DR2 \geq DR1$

4. QR must be greater than or equal to zero (i.e., upward load is not permitted).

5. If {'side'} = 'Both', mirror image ramp loads are applied to the surface on each side of the wall.

(4) Triangular loads--Zero (0) or one (1) or more lines

(a) Line contents

LN 'Vertical Triangular' {'side'} NVT

DT1(1) DT2(1) DT3(1) QT(1)

[. . . DT1(n) DT2(n) DT3(n) QT(n)]

(b) Definitions

'Vertical Triangular' = subsection title.

{'side'} = 'Rightside', 'Leftside',or 'Both'.

NVT = number (1 to 21) of triangular loads.

DT1(i) = distance (FT) from wall to beginning of triangular load.

DT2(i) = distance (FT) from wall to peak of triangular load.

DT3(i) = distance (FT) from wall to end of triangular load.

QT(i) = magnitude (PSF) of load at peak of triangular load, positive downward.

(c) Discussion

1. A triangular load is interpreted as acting on the horizontal projection of the surface.

2. Up to 21 triangular loads may be applied on either side of the wall. Quartets of DT1(i), DT2(i), DT3(i), and QT(i) may be continued on subsequent lines following a line number.

3. Distances must conform to:

   DT1(i) ≥ Zero

   DT2(i) > DT1(i) if DT3(i) = DT2(i)

   DT3(i) > DT2(i) if DT2(i) = DT1(i)

   DT3(i) > DT1(i)

4. QT(i) must be greater than or equal to zero (i.e., upward loads are not permitted).

5. If {'side'} = 'Both', mirror image triangular loads are applied to the surface on each side of the wall.

(5) Variable distributed loads--Zero (0) or one (1) or more lines

(a) Line contents

LN 'Vertical Variable' {'side'} NVV DV(1) QV(1)

[DV(2) QV(2) . . . DV(n) QV(n)]

(b) Definitions

'Vertical Variable' = subsection title.

{'side'} = 'Rightside', 'Leftside', or 'Both'.

NVV = number (2 to 21) of points on variable load distribution.

DV(i) = distance (FT) to ith point on distribution.

QV(i) = magnitude (PSF) of distributed load at ith point on distribution, positive downward.

(c) Discussion

1. A variable load distribution is interpreted as acting on the horizontal projection of the surface.

2. At least two points on a distribution are required. Up to 21 points are permitted. Points on the distribution must conform to:

$DV(1) \geq$ Zero

$DV(i) > DV(i-1)$

3. QV(i) must be greater than or equal to zero (i.e., upward loads are not permitted).

4. Only one variable distribution is permitted on each side of the wall.

5. If {'side'} = 'Both', mirror image distributions are applied to the surfaces on each side of the wall.

18. HORIZONTAL LOADS--Zero (0) or one (1) or more lines; entire section may be omitted.

a. Horizontal line loads--Zero (0) or one (1) or more lines

(1) Line contents

LN 'Horizontal Line' NHL ELL(1) HL(1)

[. . . ELL(n) HL(n)]

(2) Definitions

'Horizontal Line' = subsection title.

NHL = number (1 to 21) of line loads.

ELL(i) = elevation (FT) at ith line load.

HL(i) = magnitude (PLF) of ith line load, positive to left.

(3) Discussion

(a) Up to 21 horizontal line loads may be applied to the wall. Pairs of EL(i), HL(i) may be continued on subsequent lines following a line number.

(b) ELL(i) must be less than TOPEL.

b. Horizontal distributed loads--Zero (0) or one (1) or more lines

(1) Line contents

LN 'Horizontal Distributed' NHD ELD(1) HD(1)

ELD(2) HD(2) [. . . ELD(n) HD(n)]

(2) Definitions

'Horizontal Distributed' = subsection title

NHD = number (2 to 21) of points on load distribution.

ELD(i) = elevation (FT) at ith point on distribution.

HD(i) = magnitude (PSF) of distributed load at ith point on distribution.

(3) Discussion

(a) A least two (2) points on a distribution are required. Up to 21 points are permitted. Pairs of ELD(i), HD(i) may be continued on subsequent lines following a line number.

(b) Points on the distribution must conform to:

$ELD(1) \leq ELTOP$

$ELD(i) < ELD(i-1)$

$ELD(NHD) \geq MIN$ (Rightside ELSUR(1), Leftside ELSUR(1))

c. Horizontal earthquake acceleration--Zero (0) or one (1) line

(1) Line contents

LN 'Horizontal Acceleration' EQACC

(2) Definitions

'Horizontal Acceleration' = subsection title.

EQACC = earthquake acceleration (G's), positive numer, $0.0 \leq EQACC < 1.0$.

(3) Discussion

(a) Earthquake acceleration is assumed to increase horizontal soil and water loads on their right side and to decrease horizontal soil and water loads on the left side of the wall.

(b) If a water pressure distribution has been provided, earthquake effects on water pressure are ignored.

19. TERMINATION--One (1) line

a. Line contents

LN 'Finish' [{'option'}]

b. Definitions

'Finish' = keyword.

{'option'} = 'Keep' or 'New'; omit it this is last line in data file.

c. Discussion

(1) If {'option'} = 'Keep', data sections (or subsections) which follow up to next 'Finish' replace corresponding sections (or subsections) in preceding problem and program automatically restarts. The 'Keep' option provides for replacing part of the data in the preceding problem without reentering an entire problem description, e.g.,

1000 'NEW HEADING LINE 1

1010 'NEW HEADING LINE 1

Replaces all previous heading lines.

2000 CONTROL ANCHORED ANALYSIS

Results in analysis of an anchored wall. This alteration may require a new 'Wall' data section.

3000 VERTICAL LINE RIGHTSIDE 10. 100.

Replaces all vertical line loads on the rightside surface with a single load of 100 PLF at 10 FT from the wall.

(2) If {'option'} = 'Keep' and a section (or subsection) title appears without other data on the line, that section (or subsection) is omitted, e.g.,

4000 VERTICAL STRIP LEFTSIDE

Removes all 'Strip' loads on the leftside surface; rightside loads are unaffected.

4010 VERTICAL

Removes all vertical loads on both surfaces.

(3) A required section or subsection may not be removed--only replaced.

(4) If {'option'} = 'New', it is assumed that an entire new problem description follows and the program automatically restarts. The 'New' option provides for solving several separate problems using a single input data file.

Abbreviated Input Guide

20. HEADING--One (1) to four (4) lines

    LN 'heading'

    [LN 'heading']

    [LN 'heading']

    [LN 'heading']

21. CONTROL--One (1) line

    LN 'Control' {'Cantilever' / 'Anchored'} {'Design' / 'Analysis'} [FSA1 [FSP1]]

22. WALL DATA--One (1) line

    LN 'WALI' ELTOP [ELANCH] [ELBOT WALLE WALLI]

23. SURFACE DATA--One (1) or more lines

    LN {'SUrface'} {'side'} NSUR DSUR(1) ELSUR(1) [DSUR(2) ELSUR(2) . . . DSUR(n) ELSUR(n)]

24. SOIL DATA--Two (2) or more lines

a. Control--one (1) line

LN 'SOil' ('side') {'Strengths' / 'Coefficients'} NLAY [FSA2 [FSP2]]

b. Layer data--NLAY lines

(1) Data lines for 'Strengths'

LN GAMSAT GAMMST PHI C DELTA
ADH [ELLAYB SLOBOT] [FSA3 [FSP3]]

(2) Data lines for 'Coefficients'

LN GAMSAT GAMMST AK PK [ELLAYB]

25. WATER DATA--Zero (0) or one (1) or more lines

a. Water elevation data

LN 'WATer Elevations' GAMWAT ELWATR ELWATL

[ELSEEP {SEEP / 'Automatic' }]

b. Water pressure data

LN 'WATer Pressure' NWPR ELWPR(1) WPR(1) ELWPR(2)
WPR(2)

[LN ELWPR(3) WPR(3) . . . ELWPR(n) WPR(n)]

26. VERTICAL LOAD DATA

a. Line loads--Zero (0) or one (1) or more lines

LN 'Vertical Line' ('side') NVL DL(1) QL(1)

[LN DL(2) QL(2) . . . DL(n) QL(n)]

b. Uniform load--Zero (0) to two (2) lines

LN 'Vertical Uniform' ('side') QU

c. Strip loads--Zero (0) or one (1) or more lines

LN 'Vertical Strip' ('side') NVS DS1(1) DS2(1) QS(1)

[LN DS1(2) DS2(2) QS(2) . . . DS1(n) DS2(n) QS(n)]

d. Ramp loads--Zero (0) or one (1) line

LN 'Vertical Ramp' ('side') DR1 DR2 QR

e. Triangular loads--Zero (0) or one (1) or more lines

LN 'Vertical Triangular' ('side') NVT DT1(1) DT2(1)
DT3(1) QT(1)

[LN DT1(2) DT2(2) DT3(2) QT(2) . . . DT1(n) DT2(n)
DT3(n) QT(n)]

f. Variable loads--Zero (0) or one (1) or more lines

LN 'Vertical Variable' ('side') NVV DV(1) QV(1)
DV(2) QV(2)

[LN DV(3) QV(3) . . . DV(n) QV(n)

27. HORIZONTAL LOAD DATA

a. Line loads--Zero (0) or one (1) or more lines

LN 'Horizontal Line' NHL ELL(1) HL(1)

[LN ELL(2) HL(2) . . . ELL(n) HL(n)]

b. Distributed loads--Zero (0) or one (1) or more lines

LN 'Horizontal Distributed' NHD ELD(1) HD(1) ELD(2) HD(2)

[LN ELD(3) HD(3) . . . ELD(n) HD(n)]

c. Earthquake acceleration--Zero (0) or one (1) line

LN 'Horizontal Acceleration' EQACC

28. TERMINATION--One (1) line

LN 'Finish' [{'Keep' / 'New'}]

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

	Title	Date
Technical Report K-78-1	List of Computer Programs for Computer-Aided Structural Engineering	Feb 1978
Instruction Report O-79-2	User's Guide: Computer Program with Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Mar 1979
Technical Report K-80-1	Survey of Bridge-Oriented Design Software	Jan 1980
Technical Report K-80-2	Evaluation of Computer Programs for the Design/Analysis of Highway and Railway Bridges	Jan 1980
Instruction Report K-80-1	User's Guide: Computer Program for Design/Review of Curvilinear Conduits/Culverts (CURCON)	Feb 1980
Instruction Report K-80-3	A Three-Dimensional Finite Element Data Edit Program	Mar 1980
Instruction Report K-80-4	A Three-Dimensional Stability Analysis/Design Program (3DSAD)	
	Report 1: General Geometry Module	Jun 1980
	Report 3: General Analysis Module (CGAM)	Jun 1982
	Report 4: Special-Purpose Modules for Dams (CDAMS)	Aug 1983
Instruction Report K-80-6	Basic User's Guide: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Instruction Report K-80-7	User's Reference Manual: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Dec 1980
Technical Report K-80-4	Documentation of Finite Element Analyses	
	Report 1: Longview Outlet Works Conduit	Dec 1980
	Report 2: Anchored Wall Monolith, Bay Springs Lock	Dec 1980
Technical Report K-80-5	Basic Pile Group Behavior	Dec 1980
Instruction Report K-81-2	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CSHTWAL)	
	Report 1: Computational Processes	Feb 1981
	Report 2: Interactive Graphics Options	Mar 1981
Instruction Report K-81-3	Validation Report: Computer Program for Design and Analysis of Inverted-T Retaining Walls and Floodwalls (TWDA)	Feb 1981
Instruction Report K-81-4	User's Guide: Computer Program for Design and Analysis of Cast-in-Place Tunnel Linings (NEWTUN)	Mar 1981
Instruction Report K-81-6	User's Guide: Computer Program for Optimum Nonlinear Dynamic Design of Reinforced Concrete Slabs Under Blast Loading (CBARCS)	Mar 1981
Instruction Report K-81-7	User's Guide: Computer Program for Design or Investigation of Orthogonal Culverts (CORTCUL)	Mar 1981
Instruction Report K-81-9	User's Guide: Computer Program for Three-Dimensional Analysis of Building Systems (CTABS80)	Aug 1981
Technical Report K-81-2	Theoretical Basis for CTABS80: A Computer Program for Three-Dimensional Analysis of Building Systems	Sep 1981
Instruction Report K-82-6	User's Guide: Computer Program for Analysis of Beam-Column Structures with Nonlinear Supports (CBEAMC)	Jun 1982
Instruction Report K-82-7	User's Guide: Computer Program for Bearing Capacity Analysis of Shallow Foundations (CBEAR)	Jun 1982

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WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

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	Title	Date
Instruction Report K-83-1	User's Guide: Computer Program With Interactive Graphics for Analysis of Plane Frame Structures (CFRAME)	Jan 1983
Instruction Report K-83-2	User's Guide: Computer Program for Generation of Engineering Geometry (SKETCH)	Jun 1983
Instruction Report K-83-5	User's Guide: Computer Program to Calculate Shear, Moment, and Thrust (CSMT) from Stress Results of a Two-Dimensional Finite Element Analysis	Jul 1983
Technical Report K-83-1	Basic Pile Group Behavior	Sep 1983
Technical Report K-83-3	Reference Manual: Computer Graphics Program for Generation of Engineering Geometry (SKETCH)	Sep 1983
Technical Report K-83-4	Case Study of Six Major General-Purpose Finite Element Programs	Oct 1983
Instruction Report K-84-2	User's Guide: Computer Program for Optimum Dynamic Design of Nonlinear Metal Plates Under Blast Loading (CSDOOR)	Jan 1984
Instruction Report K-84-7	User's Guide: Computer Program for Determining Induced Stresses and Consolidation Settlements (CSETT)	Aug 1984
Instruction Report K-84-8	Seepage Analysis of Confined Flow Problems by the Method of Fragments (CFRAG)	Sep 1984
Instruction Report K-84-11	User's Guide for Computer Program CGFAG, Concrete General Flexure Analysis with Graphics	Sep 1984
Technical Report K-84-3	Computer-Aided Drafting and Design for Corps Structural Engineers	Oct 1984
Technical Report ATC-86-5	Decision Logic Table Formulation of ACI 318-77, Building Code Requirements for Reinforced Concrete for Automated Constraint Processing, Volumes I and II	Jun 1986
Technical Report ITL-87-2	A Case Committee Study of Finite Element Analysis of Concrete Flat Slabs	Jan 1987
Instruction Report ITL-87-1	User's Guide: Computer Program for Two-Dimensional Analysis of U-Frame Structures (CUFRAM)	Apr 1987
Instruction Report ITL-87-2	User's Guide: For Concrete Strength Investigation and Design (CASTR) in Accordance with ACI 318-83	May 1987
Technical Report ITL-87-6	Finite-Element Method Package for Solving Steady-State Seepage Problems	May 1987
Instruction Report ITL-87-3	User's Guide: A Three Dimensional Stability Analysis/Design Program (3DSAD) Module	Jun 1987
	Report 1: Revision 1: General Geometry	Jun 1987
	Report 2: General Loads Module	Sep 1989
	Report 6: Free-Body Module	Sep 1989
Instruction Report ITL-87-4	User's Guide: 2-D Frame Analysis Link Program (LINK2D)	Jun 1987
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate	Aug 1987
	Report 1: Initial and Refined Finite Element Models (Phases A, B, and C), Volumes I and II	

(Continued)

WATERWAYS EXPERIMENT STATION REPORTS PUBLISHED UNDER THE COMPUTER-AIDED STRUCTURAL ENGINEERING (CASE) PROJECT

(Continued)

	Title	Date
Technical Report ITL-87-4	Finite Element Studies of a Horizontally Framed Miter Gate Report 2: Simplified Frame Model (Phase D) Report 3: Alternate Configuration Miter Gate Finite Element Studies—Open Section Report 4: Alternate Configuration Miter Gate Finite Element Studies—Closed Sections Report 5: Alternate Configuration Miter Gate Finite Element Studies—Additional Closed Sections Report 6: Elastic Buckling of Girders in Horizontally Framed Miter Gates Report 7: Application and Summary	Aug 1987
Instruction Report GL-87-1	User's Guide: UTEXAS2 Slope-Stability Package; Volume I, User's Manual	Aug 1987
Instruction Report ITL-87-5	Sliding Stability of Concrete Structures (CSLIDE)	Oct 1987
Instruction Report ITL-87-6	Criteria Specifications for and Validation of a Computer Program for the Design or Investigation of Horizontally Framed Miter Gates (CMITER)	Dec 1987
Technical Report ITL-87-8	Procedure for Static Analysis of Gravity Dams Using the Finite Element Method — Phase Ia	Jan 1988
Instruction Report ITL-88-1	User's Guide: Computer Program for Analysis of Planar Grid Structures (CGRID)	Feb 1988
Technical Report ITL-88-1	Development of Design Formulas for Ribbed Mat Foundations on Expansive Soils	Apr 1988
Technical Report ITL-88-2	User's Guide: Pile Group Graphics Display (CPGG) Post-processor to CPGA Program	Apr 1988
Instruction Report ITL-88-2	User's Guide for Design and Investigation of Horizontally Framed Miter Gates (CMITER)	Jun 1988
Instruction Report ITL-88-4	User's Guide for Revised Computer Program to Calculate Shear, Moment, and Thrust (CSMT)	Sep 1988
Instruction Report GL-87-1	User's Guide: UTEXAS2 Slope-Stability Package; Volume II, Theory	Feb 1989
Technical Report ITL-89-3	User's Guide: Pile Group Analysis (CPGA) Computer Group	Jul 1989
Technical Report ITL-89-4	CBASIN--Structural Design of Saint Anthony Falls Stilling Basins According to Corps of Engineers Criteria for Hydraulic Structures; Computer Program X0098	Aug 1989
Technical Report ITL-89-5	CCHAN--Structural Design of Rectangular Channels According to Corps of Engineers Criteria for Hydraulic Structures; Computer Program X0097	Aug 1989
Technical Report ITL-89-6	The Response-Spectrum Dynamic Analysis of Gravity Dams Using the Finite Element Method; Phase II	Aug 1989
Contract Report ITL-89-1	State of the Art on Expert Systems Applications in Design, Construction, and Maintenance of Structures	Sep 1989
Instruction Report ITL-90-1	User's Guide: Computer Program for Design and Analysis of Sheet Pile Walls by Classical Methods (CWALSHT)	Feb 1990